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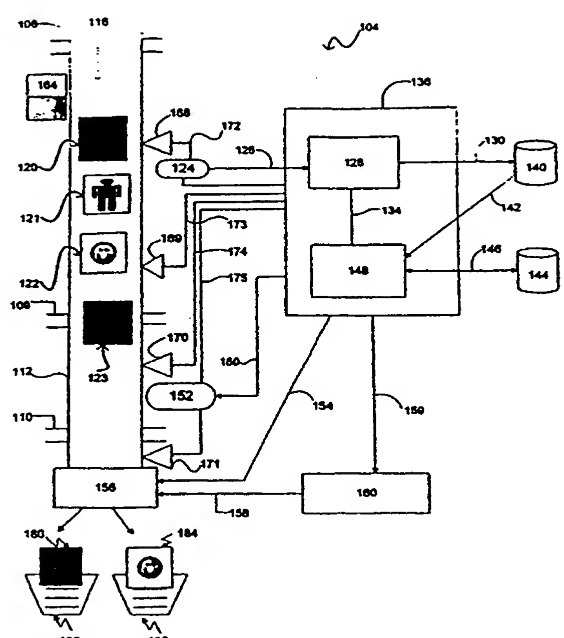

(57) Abstract: System and method for inspecting prints. An electronic processor is used to determine whether prints are characterized by an image-quality level that falls outside a predetermined range. The electronic processor comprises an artificial neural network trained to recognize good prints and bad prints based on histograms, statistical abstractions or raw pixel data derived from digital images representing each print.

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PRINT INSPECTION SYSTEM

RELATED APPLICATIONS

This application claims priority under 35 U.S.C. 119 to provisional application 60/150,075, filed August 20, 1999, the entirety of which is incorporated herein by reference.

FIELD OF THE INVENTION

The present invention relates generally to the field of photography, and more particularly to photographic film processing. Still more particularly, the present invention relates to the task of inspecting photographic prints for defects in exposure and image-quality and sorting out defective prints before they are sent to the customer.

RELATED ART

Photographic prints are typically inspected in photo finishing laboratories by trained operators who manually apply infrared absorbent stickers to prints that come out of the developing process blank, fogged or otherwise damaged beyond a level at which the print can be sold. In addition to problems caused by over and under exposure, photographic prints can have physical defects, such as scratches, water spots, edge damage or emulsion tears. Sometimes prints are damaged by repetitive exposure errors. These kinds of defects, which can be the result of a hair or film chip falling onto the exposure mechanism of the image printer, for example, can affect a large number of prints.

Current methods for inspecting prints require human intervention. A human being must manually examine every single print to determine whether the print should be rejected. Unfortunately, photo processing is much more expensive and time-consuming when a human being is involved. For example, when a human inspects prints moving on an assembly line, the human must periodically stop the assembly line in order to afford the time necessary to closely examine a particular print and make a decision about whether the print should be accepted or rejected. Thus, the whole photo processing

job is slowed down tremendously because of the human interaction, which causes the process to stop and start over and over again.

Many human operators are trained in the art of recognizing defects. But the training itself is expensive and time consuming. Plus, an employer never knows whether he will see a return on training investment dollars because human beings tend to quit, retire, take other jobs, get sick, or otherwise stop performing the inspection task for which they have been trained. Moreover, no matter how well a human is trained in the art of inspecting prints, the decision to accept or reject a particular print is ultimately an entirely subjective decision. Thus, even for a group of highly trained individuals, results will be inconsistent, depending on which operator is doing the inspection.

Another way of overcoming the problems with bad prints is to use very sophisticated printing equipment. Typically, these printers operate by scanning the image contained in a frame of film in a number of different ways to ascertain which bands of light are present as a result of incorrect exposure. These printers then either attempt to print the image in such a way as to overcome the defect, or simply skip images that contain defects printing adjustments cannot overcome. Unfortunately, there are some very significant drawbacks to using printers to identify and reject defective prints.

First, the printers are extremely expensive. Second, they add an unacceptable amount of additional time to the photo finishing process. Third, they do not address defects that come about as a result of something that occurs during or after the image printing process, such as foreign objects falling in the optical path, physical paper damage, defective printing equipment, incorrect paper development and numerous other problems, some of which are not immediately obvious. And fourth, using more sophisticated printers has not been found to be as reliable for rejecting defective prints as using human beings, mainly because printers can only identify incorrect exposures within a very limited range.

Accordingly, there is a need recognized by inventors in the photo processing industry for fast, consistent and economical method for detecting and rejecting prints that are defective without human intervention.

SUMMARY OF THE INVENTION

The present invention is directed to an automated system and method for inspecting photographic prints, detecting defects in those prints, and removing the defective prints from the job. In one aspect of the present invention, a print inspection system is provided that comprises: a transport mechanism for moving a length of paper containing a plurality of prints along a work path; a scanner, positioned along the work path, configured to capture a visual image of each print; means, coupled to the scanner, for converting the visual image of each print into a digital file corresponding to the visual image; and an electronic processor that determines whether the visual image is characterized by an image-quality level that falls inside a predetermined image-quality range. In the preferred embodiment, the electronic processor is comprised of an artificial neural network processor trained to recognize digital files having image-quality levels that fall outside the predetermined range.

The print inspection station of the present invention can also comprise means for storing the digital files corresponding to the visual images contained on the prints in a storage medium for later processing. In a further preferred embodiment, the result of the image-quality level determination can also be stored in a storage medium.

Although the above-summarized embodiments are directed to detecting prints characterized by an image-quality level that falls outside a predetermined range, person of skill in the art would recognize that the same results could be achieved by alternate means, such as detecting prints characterized by image-quality levels that fall inside a predetermined range. Such alternate means are considered within the scope of the present invention.

In another aspect of the present invention, prints determined to image quality levels that fall outside a predetermined range are marked as defective. In yet another aspect of the present invention, prints so marked are automatically discarded. In still another aspect of the current invention, the print inspection system also includes means for tracking the current location of a print as it moves along the work path. This preferred embodiment also includes means for transmitting the image-quality level and current location of that print within the work path to another print processing device.

In still a further aspect of the present invention, a method or process for inspecting prints is provided. The method comprises the steps of: feeding into a work path a length of paper containing a plurality of prints; capturing a visual image of each print; converting the visual image of each print into a digital file corresponding to the visual image; determining whether the visual image is characterized by an image-quality level that falls outside a predetermined image-quality range; and repeating the determining step for each digital file created. In the preferred embodiment of this method, an electronic processor is used to make the image-quality determination. In yet a further preferred embodiment of this method, an artificial neural network processor trained to recognize the visual images characterized by an image-quality level that fall outside the predetermined image-quality range is utilized.

Features and Advantages of the Present Invention

It is a feature of the present invention that photographic prints are inspected, and defective prints are rejected without human intervention.

It is another feature of the present invention that the results of the print inspection are consistent.

It is a further feature of the present invention that the print inspection process can be accomplished at speeds up to 5 times faster than the typical method involving human interaction.

An advantage of the present invention is that it lowers the cost of inspecting photographic prints because no human intervention is required.

A further advantage of the present invention is that it speeds up the print inspection process because, unlike human-based systems, the system of the present invention operates continuously and at speeds attainable only through the use of machines and computer programs.

Additional features and advantages of the invention are set forth in part in the description that follows, and in part are apparent from the description, or may be learned by practice of the invention. The features and advantages of the invention may also be realized and attained by means of the instrumentalities and combinations particularly set out in the appended claims.

BRIEF DESCRIPTION OF THE FIGURES

The accompanying drawings, which are incorporated in and constitute part of the specification, illustrate preferred embodiments of the invention, and, together with the description, serve to explain the principles of the present invention. In the drawings, like reference numbers indicate identical or functionally similar elements. Additionally, the left-most digit(s) of a reference number identifies the drawing in which the reference number first appears.

FIG. 1 shows a block diagram of one embodiment of a print inspection system according to the present invention.

FIG. 2 depicts a flow diagram of the training phase of an artificial neural network processor trained to distinguish between good prints and reject prints.

FIGs. 3A and 3B depict a flow diagram for a method for inspecting prints in accordance with the present invention.

FIG. 4 depicts an exemplary computer system, suitable for use with the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Reference will now be made in detail to the preferred embodiments of the invention, examples of which are illustrated in the accompanying drawings. Notably, the present invention may be implemented using software, hardware or any combination thereof, as would be apparent to those of ordinary skill in the art, and the figures and examples below are not meant to limit the scope of the present invention or its embodiments or equivalents.

Overview of the Present Invention

The present invention makes it possible for new and existing photo processing systems to efficiently and accurately perform an inspection of prints and reject those prints that are defective, all without human intervention. An electronic processor is equipped with an artificial neural network that is trained to accept or reject prints based on histograms of the image data, statistical abstractions, such as minimum, maximum and standard deviation, range, etc., on raw pixel data or a subset of raw pixel data (sampled data). The prints are tracked as they move through the system on a continuous web of paper, which makes it possible to detect and sort out the defective prints.

Detailed Operation f the Present Invention

With reference now to FIG. 1, a block diagram of one embodiment of a print inspection system 104 in accordance with the present invention is shown. The print inspection system is comprised of a transport mechanism, shown as rollers 108, 109 and 110 in FIG. 1, a scanner 124, a digitizer 128 and an electronic processor 136. Transport mechanism rollers 108, 109 and 110 move a length of paper 112 along a work path 116. The length of paper 112 contains a plurality of prints 120, 121, 122 and 123 to be processed by print-processing devices disposed along the length of the work path 116.

The scanner 124 captures a visual image of each print and sends analog signals representing the visual image to digitizer 128 via link 126. In the preferred embodiment, digitizer 128 comprises an analog-to-digital converter (not shown) suitable for converting the analog signals from scanner 124 into a digital file corresponding to the visual image contained on each print 120, 121, 122 and 123. In practice, digitizer 128 may reside in electronic processor 136, as shown in FIG. 1, or it could reside in scanner 124, an alternate embodiment not illustrated for brevity. Once the digital file is created, it is sent via link 134 to an artificial neural network processor 148, which determines, based on operations performed on the digital file, whether an image-quality level that falls outside a predetermined image-quality range characterizes the visual image. A person of skill in the art would recognize that the system could alternatively be implemented in such a way that it determines whether the image-quality level falls *inside* a predetermined image-quality range, instead of *outside* of it. A detailed description of the training and operation of the artificial neural network 148 is provided below.

In the preferred embodiment, the print inspection system of the present invention includes a storage medium 140, coupled to digitizer 128 via link 130 and the artificial neural network processor via link 142, for storing the digital files corresponding to the visual images contained on prints 120, 121, 122 and 123. Storage medium 140 could comprise any mass storage device, such as a hard drive, CDROM drive, DVD drive, tape drive, etc. In the most preferred embodiment, print inspection station 104 also includes a second storage medium 144, linked to artificial neural network processor 148 through link 146, for storing the results of the analysis carried out by artificial neural network 148. In practice, second storage medium 144, which could also be comprised of

any mass storage device, may be a different device or the same device as storage medium 140.

In a further embodiment of the present invention, print inspection station 104 further comprises a sort marker 152. When artificial neural network processor 148 determines that a visual image is characterized by an image-quality level outside a predetermined range, it sends a notification to other print processing devices, such as sort marker 152, indicating that the print corresponding to that visual image should be rejected. In this case, the notification signal is sent to sort marker 152 via link 150. In response to the notification, sort marker 152 marks the print in order to distinguish it from prints that are not to be rejected. For example, in the preferred embodiment, sort marker 152 applies an infrared absorbent sticker or ink-jet printer mark to the defective print. Other devices disposed along the work path 116, such as a packaging station 156, detect the sticker or ink-jet printer mark via an infrared reader, for example, and removes the defective print from the batch. In the embodiment depicted in FIG. 1, packaging station 156 cuts the paper 112 and sorts defective prints 180 into reject bin 188 and good prints 184 into keep bin 190.

In an alternative embodiment, the reject notification is sent from electronic controller 136 to a batch manager 160 via link 159. The batch manager 160 maintains an electronic record of each print's location in work path 116 and each print's image-quality status. The electronic records are updated continuously as prints move along work path 116. To facilitate the tracking of prints in work path 116, a cut marker 164 is positioned near the beginning of work path 116. Typically, cut markers are located inside the photographic image printer from which the prints came.

Cut marker 164 identifies the leading edge of each print, the trailing edge of each print, or both, as they enter the work path 116, and inserts cut marks corresponding to one or both edges on the length of paper 112. The cut marks are detected by cut mark sensors 168, 169, 170 and 171, which send location information for each print to electronic controller 136 via links 172, 173, 174 and 175, respectively. It is understood that cut mark sensors 168, 169, 170 and 171 could also be directly coupled to batch manager 160, scanner 124, or any other print processing device, as well as electronic controller 136. Indeed, in the most preferred embodiment of the present invention, the cut mark sensors trigger the image capture performed by scanner 124. It is

further understood that electronic controller 136, or a process or program residing within electronic controller 136, could implement the scan, cut mark sensing or batch manager functions.

Since batch manager 160 maintains a continuously updated electronic record of each print's location and each print's image-quality status, the print inspection station 104 of this embodiment would not require sort marker 152 or any infrared light absorbent stickers or ink-jet printer marks to identify defective prints. Instead, batch manager 160 transmits the appropriate accept or reject command to packaging station 156 at the appropriate time via link 158. In a preferred embodiment, batch manager 160 also sends other print-related data, such as size of the order, image size, envelope number, paper type, etc., to packaging station 156 or other print processing devices. In yet another alternative embodiment, the accept/reject notification is sent from electronic controller 136 directly to a packaging station 156 via link 154. Finally, packaging station 156 sorts the defective print 180 into discard bin 188 and the good print 184 into keep bin 190.

As would be apparent to one skilled in the art, the process of using an artificial neural network ("ANN") to solve problems involves two distinct phases: the training phase and operational phase. The training phase comprises the activities of: (1) building a "training set" for the ANN based on a representative sample and "correct" results as defined by a human trainer; and (2) repeatedly exposing the training set samples to the ANN along with the correct results for each sample until the ANN has "learned" how to derive the correct result for each sample on its own. In reality, the ANN does not actually "learn" how to derive the correct result, but generates an internal set of mathematical rules, which, when applied to the sample inputs, yields substantially the same results reached by the human trainer for each of the sample inputs.

At the end of the training phase, the ANN is considered to be "trained," which means it should be capable of solving similar, but new problems. The operational phase comprises exposing the "trained" ANN to new images that are similar, but not identical to those in the training set, and allowing the neural network to "decide" whether the new images meet the criteria defined by its internal rules.

There are a number of general purpose ANNs, suitable for purposes of inspecting prints in accordance with the present invention commercially available. The ANN known as Trajan 4.0, manufactured and sold by Trajan Software Ltd., for example,

more than adequately performs the job described herein. It will be recognized by those with skill in the art that any multi-layer perceptron ANN with suitable back-propagation training software would be suitable for these purposes.

In the preferred embodiment of the present invention, an ANN is trained to distinguish good prints from reject prints an abstraction of the image data, such as a set of histograms. In another preferred embodiment, the ANN recognizes good and bad prints based on raw pixel data, or a subset (or sample) of raw pixel data for each print image. In another embodiment, the ANN recognizes good prints and bad prints based on certain statistics computed from the image data, such as the maximum, minimum, average and standard deviation values of raw pixels. In these cases, specialized analog hardware, such as video peak detection and video signal averaging, can be utilized to provide certain of these statistical values in video real time for greatly enhanced accuracy. In another preferred embodiment, the ANN is trained to operate based on raw pixel data or a subset (or sample) of the raw pixel data.

A more detailed description of how to train and operate an artificial neural network in accordance with one embodiment of the present invention is now provided. In the first example, the ANN is trained to distinguish between good prints and reject prints based on a histogram of the image data. A histogram is a data array which consists of a number of variables each of which represents a range of pixel values in the sampled image. The value of each variable is equal to the number of pixels in the sampled image with values falling within the range of pixel values assigned to that variable. In the preferred embodiment, a histogram is used for input to the ANN because the histogram accounts for all pixels in its value range, even if pixels within the value range represent only a very small portion of the overall image.

With reference again to the flow diagram 200 depicted in FIG. 2, the first step for training the ANN to distinguish good prints from reject prints, is to decide how many points (pixels) will be sampled from each visual image and how many inputs and outputs are required for the ANN. See step 202 in FIG. 2. In a preferred embodiment, 307,200 points are used, since it provides a reasonably accurate representation of the quality level of a 640 x 480 size image, which is the standard resolution for a video graphics array ("VGA") monitor.

The next step, step 204, is to decide how many inputs (also referred to herein as the number of "cells" or "nodes") and outputs the ANN will have. In the preferred embodiment, the number of inputs to the ANN is defined as the square root of the number of points sampled from each visual image. Thus, when the sample size is 307,200 points, it works well to define an ANN with 554 inputs. In a preferred embodiment, a histogram is created for each cell. It is to be understood, however, that the present invention is not limited to the foregoing number of sample points, neural network inputs and histograms; alternative numbers for image sample sizes, inputs and histograms may be used without departing from the scope of the invention. The number of outputs used for the preferred embodiment of the ANN is 1, which corresponds to the accept or reject decision.

After the image sample size, number of input cells (or nodes) and outputs in the ANN and histograms have been determined, the next step, shown as step 206 in FIG. 2, is to pick a representative population of real world prints to be used in the ANN testing set. In a preferred embodiment, an adequate rule of thumb is to use approximately 100 prints for each input node in the ANN. In this case, 5,540 prints would be used. It is understood, however, that the present invention is not limited to any particular number of prints used in the testing set.

The population of prints selected for the testing set should include a reasonable number of both "good" and "bad" prints. The "good" prints should be reasonably consistent, in terms of subject matter and image-quality, with the types of photographs for which consumers are willing to pay and photo processors are willing to charge. The "bad" prints should consist of prints having the most common types of defects that render photographs unmarketable, such as photographs that are blank, fogged, torn, over- or under-exposed, etc.

The next step, depicted in flow diagram 200 as step 208, is to capture the visual image of each print in the population of test prints, preferably with scanner 124, and convert each visual image to a digital file corresponding to the visual image. In a step 210, histograms are created for each digital file. Then, in a step 212, the digital files are displayed to a human being, who makes a subjective determination as to whether the image should be "accepted" or "rejected." The effect of this determination is to tell the ANN what the human being considers to be the "correct" result. Next, in a step 214, the

histogram data, along with the human being's accept or reject decision, are assigned to a testing file, also known as a "training file."

Then, the final step, step 216, in the training phase is to repeatedly execute the ANN on the training set until the ANN is capable of reaching the correct conclusion (accept or reject) on all the images in the sample set on its own. At this point the training of the ANN is complete and the ANN can be utilized in the print inspection system 104, as described above with reference to FIG. 1, to render accept/reject decisions not on sample or test prints, but real prints.

With reference again to the flow diagram 200 in FIG. 2, the training steps for an ANN which distinguishes good prints and bad prints based on a subset of raw pixel data are now described. The process is very similar to the process for training an ANN to distinguish based on image histogram data. First, a determination is made as to the number of points (pixels) that will be sampled from each visual image. See step 202. As in the histogram example above, 307,200 points are used in the preferred embodiment, since it provides a reasonably accurate representation of the quality level of the entire image.

Next, the number of input nodes (cells) and output nodes for the ANN is decided. See step 204. Again, the square root of the number of sample points is a good rule-of-thumb for determining the number of input nodes. Thus, the ANN will have 554 input nodes (cells). Again, as in the histogram example, it is to be understood that the present invention is not limited to the foregoing number of sample points and neural network inputs; alternative image sample sizes and ANN input sizes may be used without departing from the scope of the invention. The number of outputs for the ANN is 1, which corresponds to the accept or reject decision.

After the image sample size and the number of nodes in the ANN have been determined, the next step, shown as step 206 in FIG. 2, is to pick a representative population of real world prints to be used in the ANN testing set. In a preferred embodiment, an adequate rule of thumb is to use approximately 100 prints for each input, or 5,540 prints. It is also understood, however, that the present invention is not limited to any particular number of prints used in the testing set.

The next step, depicted in flow diagram 200 as step 208, is to capture the visual image of each print in the population of test prints, preferably with scanner 124,

and convert each visual image to a digital file corresponding to the visual image. In this case, no histogram is created from the digital files, so step 210 would be skipped. Next, in a step 212, the digital files are displayed to a human being, who makes a subjective determination as to whether the image should be "accepted" or "rejected," thereby telling the ANN what the human being considers to be the "correct" result. Next, in a step 214, the raw pixel data from the digital files, along with the human being's accept or reject decisions, are assigned to the "training file."

Then, the final step in the training phase, step 216 in the diagram, is to repeatedly execute the ANN on the training set until the ANN is capable of reaching the correct conclusion (accept or reject) on all the images in the sample set on its own. Now the training of the ANN is complete and the ANN can be utilized in the print inspection system 104, described above with reference to FIG. 1, to render accept/reject decisions on real prints.

Training an ANN to recognize defects in visual images based on statistical abstractions is accomplished the same way training was accomplished for histogram data and raw pixel data in the previous two examples, except that maximum, minimum, average and standard deviation values for the sample points are used as the inputs to the ANN instead of histograms or raw pixel data.

With reference to the flow diagram depicted in FIGs. 3A and 3B, a more complete description of a method for inspecting prints according to the present invention is provided. In a step 302, a length of paper 112 containing a plurality of prints 120-124 is fed into a work path 116. In the photo processing industry, this length of paper 112 is known as a "continuous web." In a step 304, a visual image of each print in the length of paper 112 is captured, typically by a scanner 124. Scanner 124 may be implemented using a color sequential exposure system with a monochrome camera to lower costs, but a color video camera would also work well. The visual image for each print is then converted into a corresponding digital file in a step 306.

In a step 308, the digital file corresponding to the visual image (and the print) to be inspected is selected. Then, using the artificial neural network processor 148 described above, for example, a determination is made in step 310 as to whether the visual image corresponding to the digital file is characterized by an image-quality level outside a predetermined range. If the answer is "NO," then processing loops back to step

308, where another digital file corresponding to another visual image (and another print) is selected for processing. It is recognized that, in alternative embodiments, certain actions could be taken upon a determination that there are no defects in a print, such as marking the print "good."

If the visual image is determined to be characterized by an image-quality level outside a predetermined range (the answer is "YES"), then processing continues in the flow diagram shown on FIG. 3B by way of flow connector 300B. As shown in FIG. 3B at step 312, a notification of a defective print is sent to other print processing devices in the print inspection system 104. Some of these devices, such as the previously-described sort marker 152 or packaging station 156, could be disposed along the work path 116. Other devices, such as batch manager 160 or second storage medium 144, may not be disposed on the work path 116, but receive the information for subsequent processing. The notification may also be sent to still other print processing devices (not shown), such as a website server connected to an interconnected computer network like the Internet, so that a consumer or a retail clerk can log on from a remote location to check the image-quality status of a particular set of prints.

If the notification is sent to a sort marker 152, then the sort marker 152 applies an infrared light absorbent sticker or ink-jet printer mark to the defective print in a step 314. If the notification is sent to a batch manager 160, then, in a step 316, batch manager 160 updates its electronic record for that particular print, and, at the appropriate time, sends a reject instruction to packaging station 156. Finally, in a step 318, packaging station 156 sorts the defective print 180 into reject bin 188 and the good prints 184 into keep bin 190. The defective prints are then ready for discarding or further processing, as the case may be. Step 320 determines whether there are more prints to be inspected. If the answer is "YES," then processing returns to step 308 by way of flowchart connector 30A. Otherwise, processing is complete.

With reference now to FIG. 4, a more complete description of a computer system suitable for use with the preferred embodiment of the present invention is provided. The computer system 402 includes one or more processors, such as a processor 404. The processor 404 is connected to a communication bus 406. Various software embodiments are described in terms of this exemplary computer system. After reading this description,

it will become apparent to a person skilled in the relevant art how to implement the invention using other computer systems and/or computer architectures.

The computer system 402 also includes a main memory 408, preferably random access memory (RAM), and can also include a secondary memory 410. The secondary memory 410 can include, for example, a hard disk drive 412 and/or a removable storage drive 414, representing a floppy disk drive, a magnetic tape drive, an optical disk drive, etc. The removable storage drive 414 reads from and/or writes to a removable storage unit 418 in a well-known manner. The removable storage unit 418, represents a floppy disk, magnetic tape, optical disk, etc. which is read by and written to by the removable storage drive 414. As will be appreciated, the removable storage unit 418 includes a computer usable storage medium having stored therein computer software and/or data.

In alternative embodiments, the secondary memory 410 may include other similar means for allowing computer programs or other instructions to be loaded into the computer system 402. Such means can include, for example, a removable storage unit 422 and an interface 420. Examples of such can include a program cartridge and cartridge interface (such as that found in video game devices), a removable memory chip (such as an EPROM, or PROM) and associated socket, and other removable storage units 422 and interfaces 420 which allow software and data to be transferred from the removable storage unit 422 to the computer system 402.

The computer system 402 can also include a communications interface 424. The communications interface 424 allows software and data to be transferred between the computer system 402 and external devices. Examples of the communications interface 424 can include a modem, a network interface (such as an Ethernet card), a communications port, a PCMCIA slot and card, etc. Software and data transferred via the communications interface 424 are in the form of signals 426 that can be electronic, electromagnetic, optical or other signals capable of being received by the communications interface 424. Signals 426 are provided to communications interface via a channel 428. A channel 428 carries signals 426 and can be implemented using wire or cable, fiber optics, a phone line, a cellular phone link, an RF link and other communications channels.

In this document, the terms "computer program medium" and "computer usable medium" are used to generally refer to media such as the removable storage device 418, a

hard disk installed in hard disk drive 412, and signals 426. These computer program products are means for providing software to the computer system 402.

Computer programs (also called computer control logic) are stored in the main memory 408 and/or the secondary memory 410. Computer programs can also be received via the communications interface 424. Such computer programs, when executed, enable the computer system 402 to perform the features of the present invention as discussed herein. In particular, the computer programs, when executed, enable the processor 404 to perform the features of the present invention. Accordingly, such computer programs represent controllers of the computer system 402.

In an embodiment where the invention is implemented using software, the software may be stored in a computer program product and loaded into the computer system 402 using the removable storage drive 414, the hard drive 412 or the communications interface 424. The control logic (software), when executed by the processor 404, causes the processor 404 to perform the functions of the invention as described herein.

In another embodiment, the invention is implemented primarily in hardware using, for example, hardware components such as application specific integrated circuits (ASICs). Implementation of such a hardware state machine so as to perform the functions described herein will be apparent to persons skilled in the relevant art(s).

In yet another embodiment, the invention is implemented using a combination of both hardware and software.

The present invention has been disclosed and described herein in what is considered to be its most preferred embodiments. It should be noted that variations and equivalents may occur to those skilled in the art upon reading the present disclosure and that such variations and equivalents are intended to come within the scope of the invention and the appended claims.

CLAIMS

What I claim is:

1. A print inspection system, comprising:

a transport mechanism for moving a length of paper along a work path, said length of paper containing a plurality of prints;

a scanner positioned along said work path, said scanner being configured to capture a visual image of each of said plurality of prints;

means, coupled to said scanner, for converting said visual image into a digital file corresponding to said visual image; and

an electronic processor, wherein said electronic processor determines whether said visual image is characterized by an image-quality level that falls outside a predetermined image-quality range.

2. The print inspection system of claim 1, wherein said electronic processor is comprised of:

a neural network processor that is trained to recognize a digital file having an image-quality level that falls outside a predetermined range of image-quality levels.

3. The print inspection system of claim 1, further comprising means for storing said digital file on a first storage medium.

4. The print inspection system of claim 3, further comprising means for storing the result of said image-quality level determination on a second storage medium.

5. The print inspection system of claim 1, further comprising:

means, responsive to said electronic processor, for marking prints corresponding to visual images characterized by an image-quality level that falls outside said predetermined image-quality range.

6. The print inspection system of claim 5, further comprising:

means for discarding prints corresponding to visual images having image-quality levels that fall outside said predetermined image-quality range.

7. The print inspection system of claim 1, further comprising:

means for tracking the current location of a print as it moves along said work path; and

means for transmitting the image-quality level of said print and current location of that print on said work path to a print-processing device.

8. The print inspection system of claim 1, further comprising means for identifying a leading and a trailing edge of each print as it moves along said work path.

9. The print inspection system of claim 8, wherein said means for identifying comprises:

a cut-marker positioned near the start of said work path, wherein said cut-marker inserts cut-marks on said length of paper corresponding to the trailing edge of each print; and

a cut-mark sensor.

10. The print inspection system of claim 7, wherein said means for tracking comprises:

a cut-marker positioned near the start of said work path, wherein said cut-marker inserts cut-marks on said length of paper corresponding to the trailing edge of each print; and

a cut-mark sensor.

11. A method for inspecting prints, comprising the steps of:

feeding into a work path a length of paper containing a plurality of prints;

capturing a visual image of each print;

converting said visual image of each print into a digital file corresponding to said visual image;

determining whether said visual image is characterized by an image-quality level that falls outside a predetermined image-quality range; and

repeating said determining step for each digital file created in said converting step.

12. The method of claim 11, wherein said determining step is carried out using an electronic processor.

13. The method of claim 11, wherein said determining step comprises:

training a neural network processor to recognize visual images characterized by an image-quality level that falls outside said predetermined image-quality range.

14. The method of claim 13, wherein said training step comprises:

training said neural network to recognize a visual image that contains no useful content.

15. The method of claim 13, wherein said training step comprises:

training said neural network to recognize a visual image that has a physical defect.

16. The method of claim 13, wherein said training step comprises:

training said neural network to recognize a visual image that has a repetitive exposure error.

17. The method of claim 13, wherein said training step is accomplished by presenting said neural network processor with a histogram of the sampled visual image.

18. The method of claim 13, wherein said training is accomplished by presenting said neural network processor with statistical abstractions of sample visual images.

19. The method of claim 13, wherein said training comprises presenting said neural network processor with raw pixel data corresponding to sample visual images.

20. The method of claim 13, wherein said training is accomplished by presenting said neural network processor with a subset of raw pixel data corresponding to sample visual images.

21. The method of claim 11, further comprising the step of storing said digital file on a first storage medium.

22. The method of claim 11, further comprising the steps of:

marking prints corresponding to visual images characterized by an image-quality level that falls outside said predetermined image-quality range to form marked prints; and

discarding said marked prints containing said markings.

23. The method of claim 11, further comprising the step of tracking the current location of each print as it moves along said work path.

24. The method of claim 23, further comprising the step of:

transmitting image-quality level of a print and current location of that print on said work path to a print-processing device.

25. The method of claim 24, wherein said image-quality level and current location are transmitted to said print-processing device via a link to an interconnected computer network.

26. A method for inspecting prints, comprising the steps of:

feeding into a work path a length of paper containing a plurality of prints;

marking a leading or trailing edge of each print with cut-marks;

sensing the location of said cut-marks as said length of paper moves along said work path; and

in response to said sensing,

capturing a visual image of each print,

converting said visual image into a digital file corresponding to said visual image, and

determining whether said visual image is characterized by an image-quality level that falls outside a predetermined image-quality range.

27. The method of claim 26, wherein said determining step is carried out using an electronic processor.

28. The method of claim 26, wherein said determining step comprises:

training a neural network processor to recognize visual images characterized by an image-quality level that falls outside said predetermined image-quality range.

29. A method for inspecting prints, comprising the steps of:

feeding into a work path a length of paper containing a plurality of prints;

capturing a visual image of each print;

converting said visual image of each print into a digital file corresponding to said visual image;

determining via an electronic processor whether said visual image is characterized by an image-quality level that falls outside a predetermined image-quality range; and

repeating said determining step for each digital file created in said converting step.

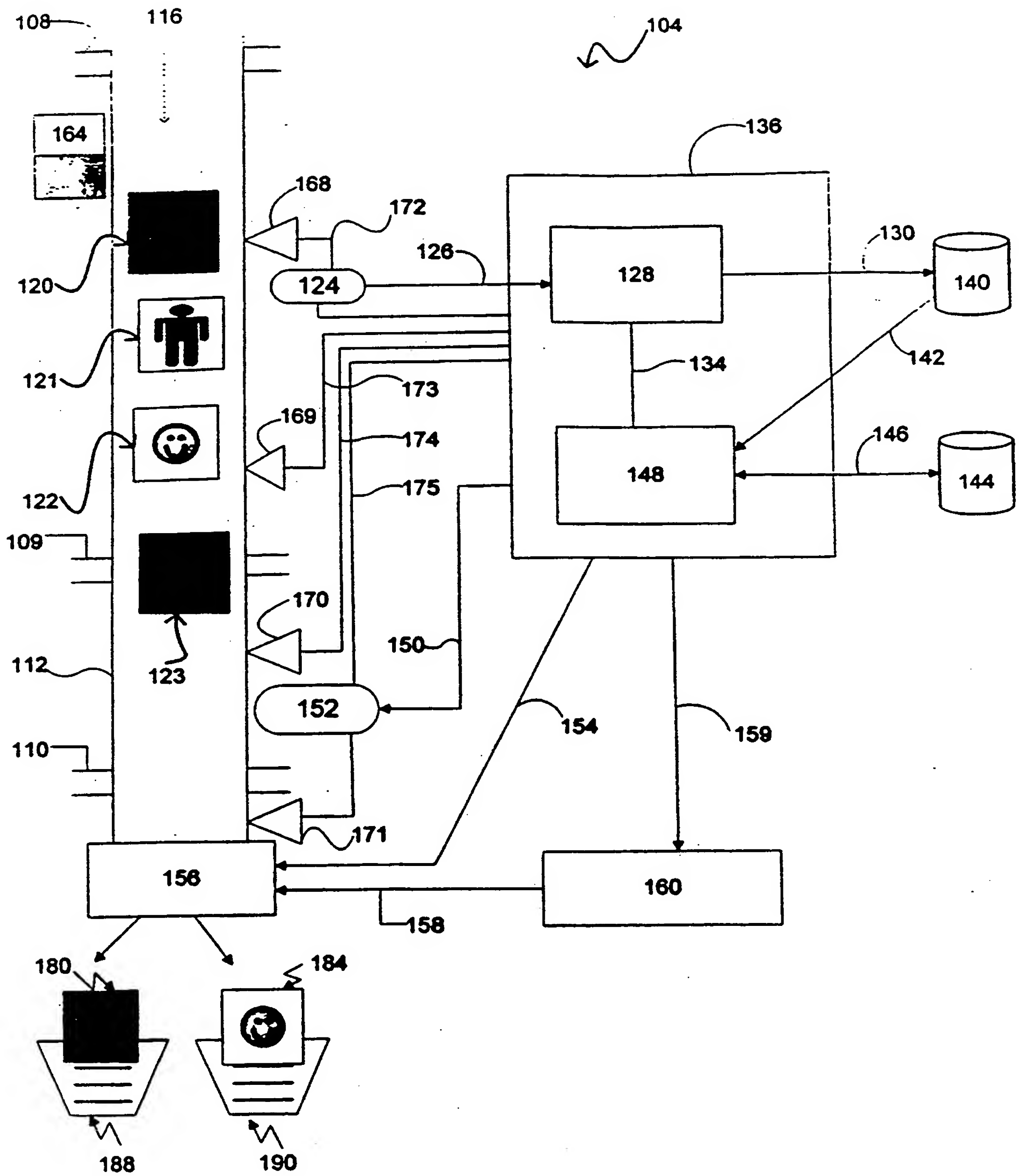

FIG. 1
Print Inspection System

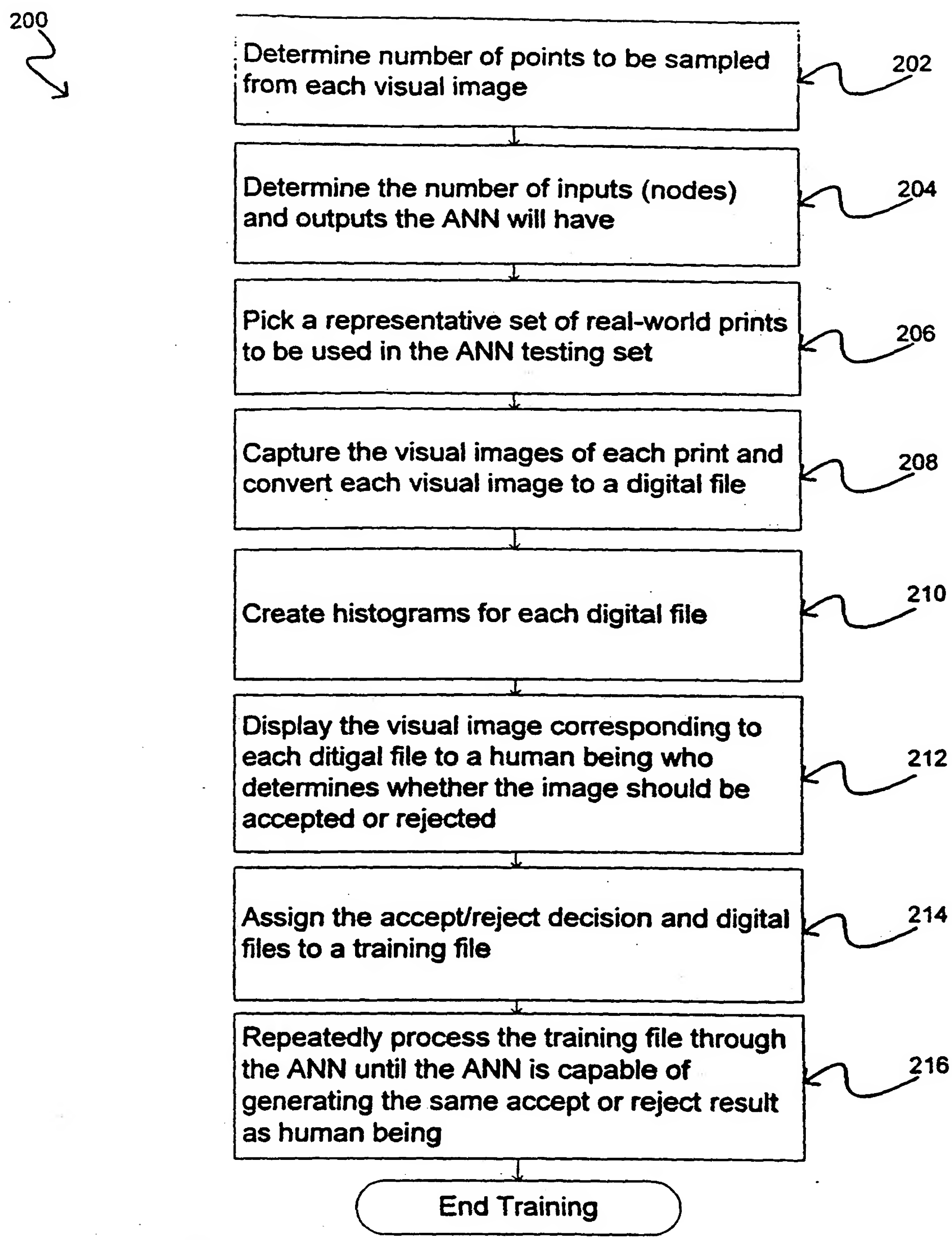

FIG. 2
PRINT INSPECTION SYSTEM
Artificial N ural Network Training
FLowchart

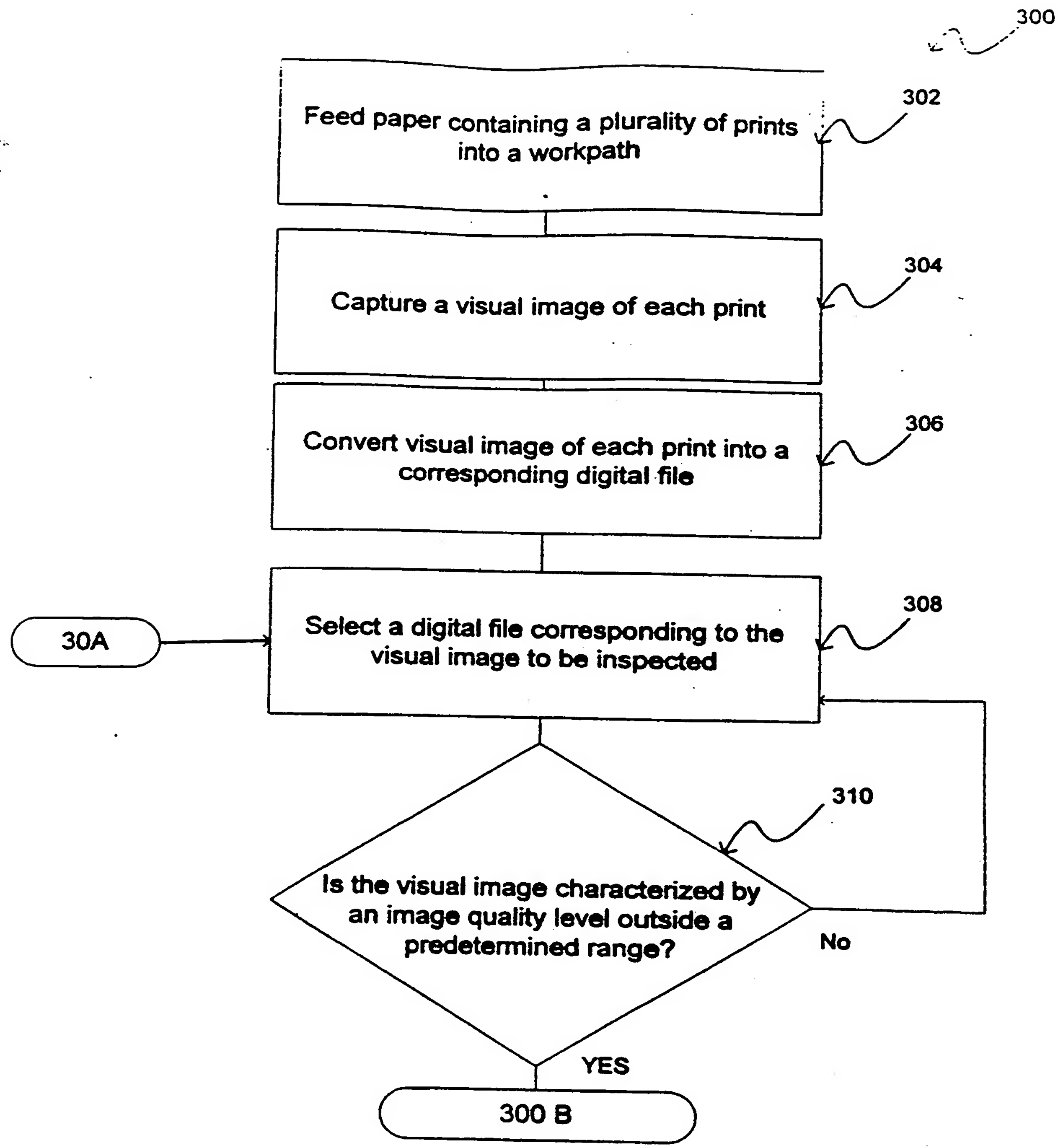

FIG. 3A
PRINT INSPECTION METHOD
Process Flowchart

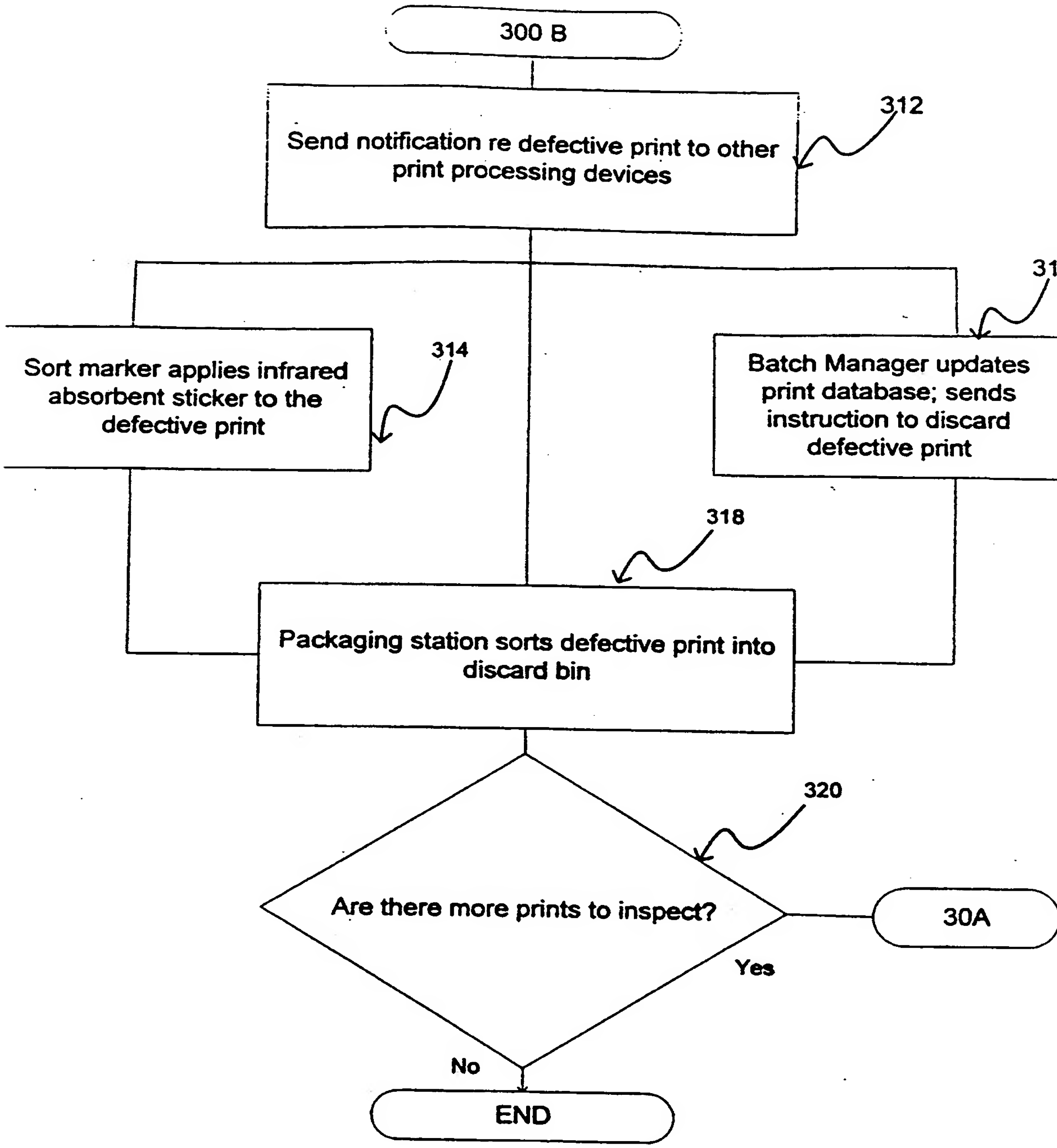

FIG. 3B
PRINT INSPECTION METHOD
Process Flowchart

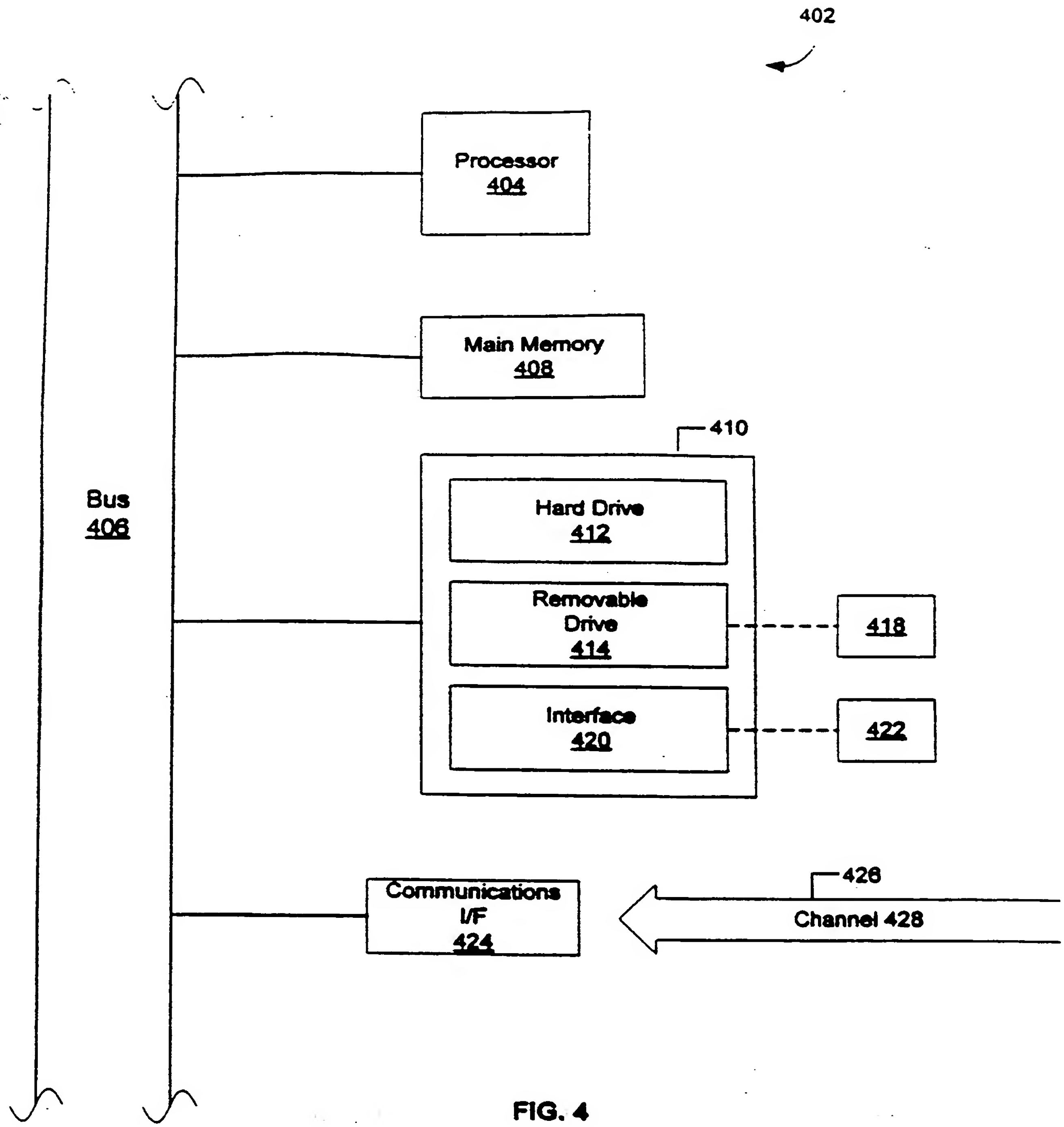
402
Processor
404
Main Memory
408
410
Bus
406
Hard Drive
412
Removable
Drive
414
418
Interface
420
422
Communications
I/F
424
426
Channel 428

FIG. 4

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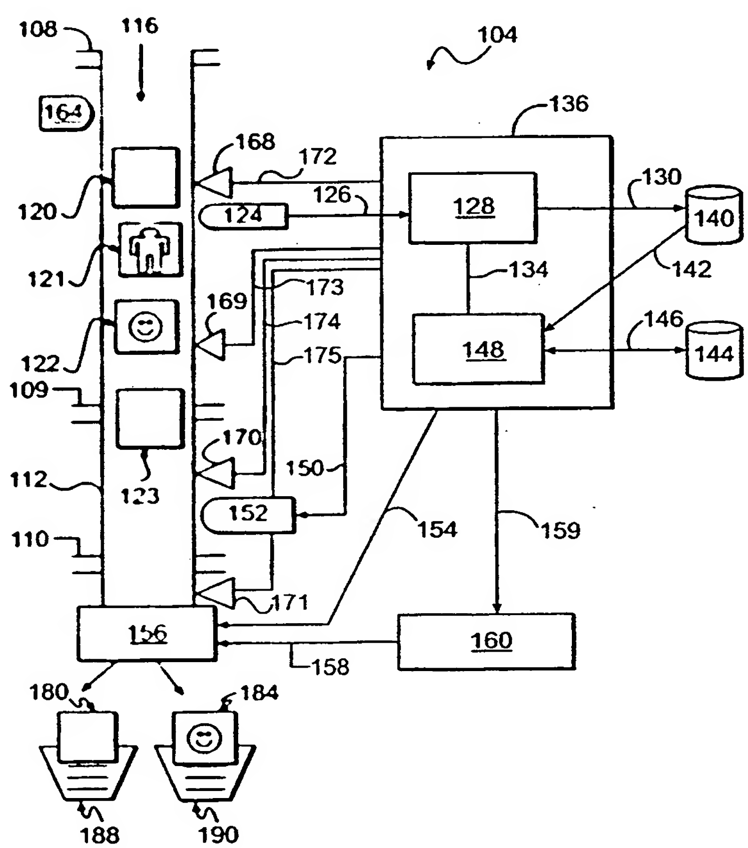
(54) Title: PRINT INSPECTION SYSTEM



(57) Abstract: System and method for inspecting prints (104). An electronic processor (136) is used to determine whether prints are characterized by an image-quality level that falls outside a predetermined range. The electronic processor (136) comprises an artificial neural network (148) trained to recognize good prints and bad prints based on histograms, statistical abstractions or raw pixel data derived from digital images representing each print.

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B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

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Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WEST 2.0

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5,841,904 A (Sugiura) 24 November 1998 (24.12.1998) see whole document	1-29
Y	US 5,309,526 A (Pappas et al)) 03 May 1994 (03.05.1994) see whole document	1-29
A	US 5,550,951 A (Woodall) 27 August 1996 (08.27.1996) See whole document	1-29

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

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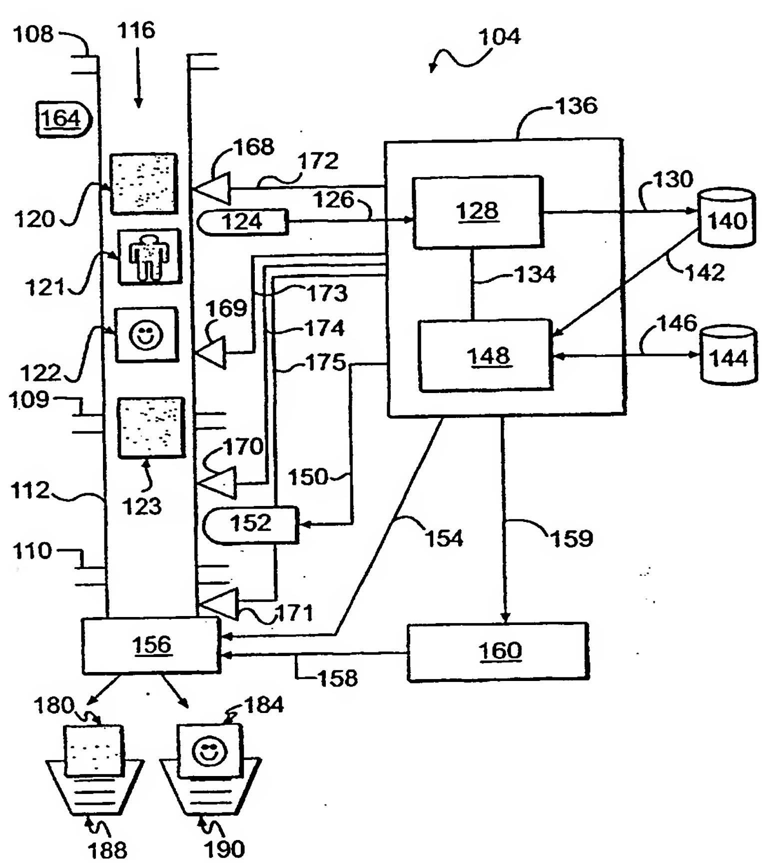
(54) Title: PRINT INSPECTION SYSTEM



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PRINT INSPECTION SYSTEM

RELATED APPLICATIONS

This application claims priority under 35 U.S.C. 119 to provisional application 60/150,075, filed August 20, 1999, the entirety of which is incorporated herein by reference.

FIELD OF THE INVENTION

The present invention relates generally to the field of photography, and more particularly to photographic film processing. Still more particularly, the present invention relates to the task of inspecting photographic prints for defects in exposure and image-quality and sorting out defective prints before they are sent to the customer.

RELATED ART

Photographic prints are typically inspected in photo finishing laboratories by trained operators who manually apply infrared absorbent stickers to prints that come out of the developing process blank, fogged or otherwise damaged beyond a level at which the print can be sold. In addition to problems caused by over and under exposure, photographic prints can have physical defects, such as scratches, water spots, edge damage or emulsion tears. Sometimes prints are damaged by repetitive exposure errors. These kinds of defects, which can be the result of a hair or film chip falling onto the exposure mechanism of the image printer, for example, can affect a large number of prints.

Current methods for inspecting prints require human intervention. A human being must manually examine every single print to determine whether the print should be rejected. Unfortunately, photo processing is much more expensive and time-consuming when a human being is involved. For example, when a human inspects prints moving on an assembly line, the human must periodically stop the assembly line in order to afford the time necessary to closely examine a particular print and make a decision about whether the print should be accepted or rejected. Thus, the whole photo processing

job is slowed down tremendously because of the human interaction, which causes the process to stop and start over and over again.

Many human operators are trained in the art of recognizing defects. But the training itself is expensive and time consuming. Plus, an employer never knows whether he will see a return on training investment dollars because human beings tend to quit, retire, take other jobs, get sick, or otherwise stop performing the inspection task for which they have been trained. Moreover, no matter how well a human is trained in the art of inspecting prints, the decision to accept or reject a particular print is ultimately an entirely subjective decision. Thus, even for a group of highly trained individuals, results will be inconsistent, depending on which operator is doing the inspection.

Another way of overcoming the problems with bad prints is to use very sophisticated printing equipment. Typically, these printers operate by scanning the image contained in a frame of film in a number of different ways to ascertain which bands of light are present as a result of incorrect exposure. These printers then either attempt to print the image in such a way as to overcome the defect, or simply skip images that contain defects printing adjustments cannot overcome. Unfortunately, there are some very significant drawbacks to using printers to identify and reject defective prints.

First, the printers are extremely expensive. Second, they add an unacceptable amount of additional time to the photo finishing process. Third, they do not address defects that come about as a result of something that occurs during or after the image printing process, such as foreign objects falling in the optical path, physical paper damage, defective printing equipment, incorrect paper development and numerous other problems, some of which are not immediately obvious. And fourth, using more sophisticated printers has not been found to be as reliable for rejecting defective prints as using human beings, mainly because printers can only identify incorrect exposures within a very limited range.

Accordingly, there is a need recognized by inventors in the photo processing industry for fast, consistent and economical method for detecting and rejecting prints that are defective without human intervention.

SUMMARY OF THE INVENTION

The present invention is directed to an automated system and method for inspecting photographic prints, detecting defects in those prints, and removing the defective prints from the job. In one aspect of the present invention, a print inspection system is provided that comprises: a transport mechanism for moving a length of paper containing a plurality of prints along a work path; a scanner, positioned along the work path, configured to capture a visual image of each print; means, coupled to the scanner, for converting the visual image of each print into a digital file corresponding to the visual image; and an electronic processor that determines whether the visual image is characterized by an image-quality level that falls inside a predetermined image-quality range. In the preferred embodiment, the electronic processor is comprised of an artificial neural network processor trained to recognize digital files having image-quality levels that fall outside the predetermined range.

The print inspection station of the present invention can also comprise means for storing the digital files corresponding to the visual images contained on the prints in a storage medium for later processing. In a further preferred embodiment, the result of the image-quality level determination can also be stored in a storage medium.

Although the above-summarized embodiments are directed to detecting prints characterized by an image-quality level that falls outside a predetermined range, person of skill in the art would recognize that the same results could be achieved by alternate means, such as detecting prints characterized by image-quality levels that fall inside a predetermined range. Such alternate means are considered within the scope of the present invention.

In another aspect of the present invention, prints determined to image quality levels that fall outside a predetermined range are marked as defective. In yet another aspect of the present invention, prints so marked are automatically discarded. In still another aspect of the current invention, the print inspection system also includes means for tracking the current location of a print as it moves along the work path. This preferred embodiment also includes means for transmitting the image-quality level and current location of that print within the work path to another print processing device.

In still a further aspect of the present invention, a method or process for inspecting prints is provided. The method comprises the steps of: feeding into a work path a length of paper containing a plurality of prints; capturing a visual image of each print; converting the visual image of each print into a digital file corresponding to the visual image; determining whether the visual image is characterized by an image-quality level that falls outside a predetermined image-quality range; and repeating the determining step for each digital file created. In the preferred embodiment of this method, an electronic processor is used to make the image-quality determination. In yet a further preferred embodiment of this method, an artificial neural network processor trained to recognize the visual images characterized by an image-quality level that fall outside the predetermined image-quality range is utilized.

Features and Advantages of the Present Invention

It is a feature of the present invention that photographic prints are inspected, and defective prints are rejected without human intervention.

It is another feature of the present invention that the results of the print inspection are consistent.

It is a further feature of the present invention that the print inspection process can be accomplished at speeds up to 5 times faster than the typical method involving human interaction.

An advantage of the present invention is that it lowers the cost of inspecting photographic prints because no human intervention is required.

A further advantage of the present invention is that it speeds up the print inspection process because, unlike human-based systems, the system of the present invention operates continuously and at speeds attainable only through the use of machines and computer programs.

Additional features and advantages of the invention are set forth in part in the description that follows, and in part are apparent from the description, or may be learned by practice of the invention. The features and advantages of the invention may also be realized and attained by means of the instrumentalities and combinations particularly set out in the appended claims.

BRIEF DESCRIPTION OF THE FIGURES

The accompanying drawings, which are incorporated in and constitute part of the specification, illustrate preferred embodiments of the invention, and, together with the description, serve to explain the principles of the present invention. In the drawings, like reference numbers indicate identical or functionally similar elements. Additionally, the left-most digit(s) of a reference number identifies the drawing in which the reference number first appears.

FIG. 1 shows a block diagram of one embodiment of a print inspection system according to the present invention.

FIG. 2 depicts a flow diagram of the training phase of an artificial neural network processor trained to distinguish between good prints and reject prints.

FIGs. 3A and 3B depict a flow diagram for a method for inspecting prints in accordance with the present invention.

FIG. 4 depicts an exemplary computer system, suitable for use with the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Reference will now be made in detail to the preferred embodiments of the invention, examples of which are illustrated in the accompanying drawings. Notably, the present invention may be implemented using software, hardware or any combination thereof, as would be apparent to those of ordinary skill in the art, and the figures and examples below are not meant to limit the scope of the present invention or its embodiments or equivalents.

Overview of the Present Invention

The present invention makes it possible for new and existing photo processing systems to efficiently and accurately perform an inspection of prints and reject those prints that are defective, all without human intervention. An electronic processor is equipped with an artificial neural network that is trained to accept or reject prints based on histograms of the image data, statistical abstractions, such as minimum, maximum and standard deviation, range, etc., on raw pixel data or a subset of raw pixel data (sampled data). The prints are tracked as they move through the system on a continuous web of paper, which makes it possible to detect and sort out the defective prints.

Detailed Operation of the Present Inventi n

With reference now to FIG. 1, a block diagram of one embodiment of a print inspection system 104 in accordance with the present invention is shown. The print inspection system is comprised of a transport mechanism, shown as rollers 108, 109 and 110 in FIG. 1, a scanner 124, a digitizer 128 and an electronic processor 136. Transport mechanism rollers 108, 109 and 110 move a length of paper 112 along a work path 116. The length of paper 112 contains a plurality of prints 120, 121, 122 and 123 to be processed by print-processing devices disposed along the length of the work path 116.

The scanner 124 captures a visual image of each print and sends analog signals representing the visual image to digitizer 128 via link 126. In the preferred embodiment, digitizer 128 comprises an analog-to-digital converter (not shown) suitable for converting the analog signals from scanner 124 into a digital file corresponding to the visual image contained on each print 120, 121, 122 and 123. In practice, digitizer 128 may reside in electronic processor 136, as shown in FIG. 1, or it could reside in scanner 124, an alternate embodiment not illustrated for brevity. Once the digital file is created, it is sent via link 134 to an artificial neural network processor 148, which determines, based on operations performed on the digital file, whether an image-quality level that falls outside a predetermined image-quality range characterizes the visual image. A person of skill in the art would recognize that the system could alternatively be implemented in such a way that it determines whether the image-quality level falls *inside* a predetermined image-quality range, instead of *outside* of it. A detailed description of the training and operation of the artificial neural network 148 is provided below.

In the preferred embodiment, the print inspection system of the present invention includes a storage medium 140, coupled to digitizer 128 via link 130 and the artificial neural network processor via link 142, for storing the digital files corresponding to the visual images contained on prints 120, 121, 122 and 123. Storage medium 140 could comprise any mass storage device, such as a hard drive, CDROM drive, DVD drive, tape drive, etc. In the most preferred embodiment, print inspection station 104 also includes a second storage medium 144, linked to artificial neural network processor 148 through link 146, for storing the results of the analysis carried out by artificial neural network 148. In practice, second storage medium 144, which could also be comprised of

any mass storage device, may be a different device or the same device as storage medium 140.

In a further embodiment of the present invention, print inspection station 104 further comprises a sort marker 152. When artificial neural network processor 148 determines that a visual image is characterized by an image-quality level outside a predetermined range, it sends a notification to other print processing devices, such as sort marker 152, indicating that the print corresponding to that visual image should be rejected. In this case, the notification signal is sent to sort marker 152 via link 150. In response to the notification, sort marker 152 marks the print in order to distinguish it from prints that are not to be rejected. For example, in the preferred embodiment, sort marker 152 applies an infrared absorbent sticker or ink-jet printer mark to the defective print. Other devices disposed along the work path 116, such as a packaging station 156, detect the sticker or ink-jet printer mark via an infrared reader, for example, and removes the defective print from the batch. In the embodiment depicted in FIG. 1, packaging station 156 cuts the paper 112 and sorts defective prints 180 into reject bin 188 and good prints 184 into keep bin 190.

In an alternative embodiment, the reject notification is sent from electronic controller 136 to a batch manager 160 via link 159. The batch manager 160 maintains an electronic record of each print's location in work path 116 and each print's image-quality status. The electronic records are updated continuously as prints move along work path 116. To facilitate the tracking of prints in work path 116, a cut marker 164 is positioned near the beginning of work path 116. Typically, cut markers are located inside the photographic image printer from which the prints came.

Cut marker 164 identifies the leading edge of each print, the trailing edge of each print, or both, as they enter the work path 116, and inserts cut marks corresponding to one or both edges on the length of paper 112. The cut marks are detected by cut mark sensors 168, 169, 170 and 171, which send location information for each print to electronic controller 136 via links 172, 173, 174 and 175, respectively. It is understood that cut mark sensors 168, 169, 170 and 171 could also be directly coupled to batch manager 160, scanner 124, or any other print processing device, as well as electronic controller 136. Indeed, in the most preferred embodiment of the present invention, the cut mark sensors trigger the image capture performed by scanner 124. It is

further understood that electronic controller 136, or a process or program residing within electronic controller 136, could implement the scan, cut mark sensing or batch manager functions.

Since batch manager 160 maintains a continuously updated electronic record of each print's location and each print's image-quality status, the print inspection station 104 of this embodiment would not require sort marker 152 or any infrared light absorbent stickers or ink-jet printer marks to identify defective prints. Instead, batch manager 160 transmits the appropriate accept or reject command to packaging station 156 at the appropriate time via link 158. In a preferred embodiment, batch manager 160 also sends other print-related data, such as size of the order, image size, envelope number, paper type, etc., to packaging station 156 or other print processing devices. In yet another alternative embodiment, the accept/reject notification is sent from electronic controller 136 directly to a packaging station 156 via link 154. Finally, packaging station 156 sorts the defective print 180 into discard bin 188 and the good print 184 into keep bin 190.

As would be apparent to one skilled in the art, the process of using an artificial neural network ("ANN") to solve problems involves two distinct phases: the training phase and operational phase. The training phase comprises the activities of: (1) building a "training set" for the ANN based on a representative sample and "correct" results as defined by a human trainer; and (2) repeatedly exposing the training set samples to the ANN along with the correct results for each sample until the ANN has "learned" how to derive the correct result for each sample on its own. In reality, the ANN does not actually "learn" how to derive the correct result, but generates an internal set of mathematical rules, which, when applied to the sample inputs, yields substantially the same results reached by the human trainer for each of the sample inputs.

At the end of the training phase, the ANN is considered to be "trained," which means it should be capable of solving similar, but new problems. The operational phase comprises exposing the "trained" ANN to new images that are similar, but not identical to those in the training set, and allowing the neural network to "decide" whether the new images meet the criteria defined by its internal rules.

There are a number of general purpose ANNs, suitable for purposes of inspecting prints in accordance with the present invention commercially available. The ANN known as Trajan 4.0, manufactured and sold by Trajan Software Ltd., for example,

more than adequately performs the job described herein. It will be recognized by those with skill in the art that any multi-layer perceptron ANN with suitable back-propagation training software would be suitable for these purposes.

In the preferred embodiment of the present invention, an ANN is trained to distinguish good prints from reject prints an abstraction of the image data, such as a set of histograms. In another preferred embodiment, the ANN recognizes good and bad prints based on raw pixel data, or a subset (or sample) of raw pixel data for each print image. In another embodiment, the ANN recognizes good prints and bad prints based on certain statistics computed from the image data, such as the maximum, minimum, average and standard deviation values of raw pixels. In these cases, specialized analog hardware, such as video peak detection and video signal averaging, can be utilized to provide certain of these statistical values in video real time for greatly enhanced accuracy. In another preferred embodiment, the ANN is trained to operate based on raw pixel data or a subset (or sample) of the raw pixel data.

A more detailed description of how to train and operate an artificial neural network in accordance with one embodiment of the present invention is now provided. In the first example, the ANN is trained to distinguish between good prints and reject prints based on a histogram of the image data. A histogram is a data array which consists of a number of variables each of which represents a range of pixel values in the sampled image. The value of each variable is equal to the number of pixels in the sampled image with values falling within the range of pixel values assigned to that variable. In the preferred embodiment, a histogram is used for input to the ANN because the histogram accounts for all pixels in its value range, even if pixels within the value range represent only a very small portion of the overall image.

With reference again to the flow diagram 200 depicted in FIG. 2, the first step for training the ANN to distinguish good prints from reject prints, is to decide how many points (pixels) will be sampled from each visual image and how many inputs and outputs are required for the ANN. See step 202 in FIG. 2. In a preferred embodiment, 307,200 points are used, since it provides a reasonably accurate representation of the quality level of a 640 x 480 size image, which is the standard resolution for a video graphics array ("VGA") monitor.

The next step, step 204, is to decide how many inputs (also referred to herein as the number of "cells" or "nodes") and outputs the ANN will have. In the preferred embodiment, the number of inputs to the ANN is defined as the square root of the number of points sampled from each visual image. Thus, when the sample size is 307,200 points, it works well to define an ANN with 554 inputs. In a preferred embodiment, a histogram is created for each cell. It is to be understood, however, that the present invention is not limited to the foregoing number of sample points, neural network inputs and histograms; alternative numbers for image sample sizes, inputs and histograms may be used without departing from the scope of the invention. The number of outputs used for the preferred embodiment of the ANN is 1, which corresponds to the accept or reject decision.

After the image sample size, number of input cells (or nodes) and outputs in the ANN and histograms have been determined, the next step, shown as step 206 in FIG. 2, is to pick a representative population of real world prints to be used in the ANN testing set. In a preferred embodiment, an adequate rule of thumb is to use approximately 100 prints for each input node in the ANN. In this case, 5,540 prints would be used. It is understood, however, that the present invention is not limited to any particular number of prints used in the testing set.

The population of prints selected for the testing set should include a reasonable number of both "good" and "bad" prints. The "good" prints should be reasonably consistent, in terms of subject matter and image-quality, with the types of photographs for which consumers are willing to pay and photo processors are willing to charge. The "bad" prints should consist of prints having the most common types of defects that render photographs unmarketable, such as photographs that are blank, fogged, torn, over- or under-exposed, etc.

The next step, depicted in flow diagram 200 as step 208, is to capture the visual image of each print in the population of test prints, preferably with scanner 124, and convert each visual image to a digital file corresponding to the visual image. In a step 210, histograms are created for each digital file. Then, in a step 212, the digital files are displayed to a human being, who makes a subjective determination as to whether the image should be "accepted" or "rejected." The effect of this determination is to tell the ANN what the human being considers to be the "correct" result. Next, in a step 214, the

histogram data, along with the human being's accept or reject decision, are assigned to a testing file, also known as a "training file."

Then, the final step, step 216, in the training phase is to repeatedly execute the ANN on the training set until the ANN is capable of reaching the correct conclusion (accept or reject) on all the images in the sample set on its own. At this point the training of the ANN is complete and the ANN can be utilized in the print inspection system 104, as described above with reference to FIG. 1, to render accept/reject decisions not on sample or test prints, but real prints.

With reference again to the flow diagram 200 in FIG. 2, the training steps for an ANN which distinguishes good prints and bad prints based on a subset of raw pixel data are now described. The process is very similar to the process for training an ANN to distinguish based on image histogram data. First, a determination is made as to the number of points (pixels) that will be sampled from each visual image. See step 202. As in the histogram example above, 307,200 points are used in the preferred embodiment, since it provides a reasonably accurate representation of the quality level of the entire image.

Next, the number of input nodes (cells) and output nodes for the ANN is decided. See step 204. Again, the square root of the number of sample points is a good rule-of-thumb for determining the number of input nodes. Thus, the ANN will have 554 input nodes (cells). Again, as in the histogram example, it is to be understood that the present invention is not limited to the foregoing number of sample points and neural network inputs; alternative image sample sizes and ANN input sizes may be used without departing from the scope of the invention. The number of outputs for the ANN is 1, which corresponds to the accept or reject decision.

After the image sample size and the number of nodes in the ANN have been determined, the next step, shown as step 206 in FIG. 2, is to pick a representative population of real world prints to be used in the ANN testing set. In a preferred embodiment, an adequate rule of thumb is to use approximately 100 prints for each input, or 5,540 prints. It is also understood, however, that the present invention is not limited to any particular number of prints used in the testing set.

The next step, depicted in flow diagram 200 as step 208, is to capture the visual image of each print in the population of test prints, preferably with scanner 124,

and convert each visual image to a digital file corresponding to the visual image. In this case, no histogram is created from the digital files, so step 210 would be skipped. Next, in a step 212, the digital files are displayed to a human being, who makes a subjective determination as to whether the image should be "accepted" or "rejected," thereby telling the ANN what the human being considers to be the "correct" result. Next, in a step 214, the raw pixel data from the digital files, along with the human being's accept or reject decisions, are assigned to the "training file."

Then, the final step in the training phase, step 216 in the diagram, is to repeatedly execute the ANN on the training set until the ANN is capable of reaching the correct conclusion (accept or reject) on all the images in the sample set on its own. Now the training of the ANN is complete and the ANN can be utilized in the print inspection system 104, described above with reference to FIG. 1, to render accept/reject decisions on real prints.

Training an ANN to recognize defects in visual images based on statistical abstractions is accomplished the same way training was accomplished for histogram data and raw pixel data in the previous two examples, except that maximum, minimum, average and standard deviation values for the sample points are used as the inputs to the ANN instead of histograms or raw pixel data.

With reference to the flow diagram depicted in FIGs. 3A and 3B, a more complete description of a method for inspecting prints according to the present invention is provided. In a step 302, a length of paper 112 containing a plurality of prints 120-124 is fed into a work path 116. In the photo processing industry, this length of paper 112 is known as a "continuous web." In a step 304, a visual image of each print in the length of paper 112 is captured, typically by a scanner 124. Scanner 124 may be implemented using a color sequential exposure system with a monochrome camera to lower costs, but a color video camera would also work well. The visual image for each print is then converted into a corresponding digital file in a step 306.

In a step 308, the digital file corresponding to the visual image (and the print) to be inspected is selected. Then, using the artificial neural network processor 148 described above, for example, a determination is made in step 310 as to whether the visual image corresponding to the digital file is characterized by an image-quality level outside a predetermined range. If the answer is "NO," then processing loops back to step

308, where another digital file corresponding to another visual image (and another print) is selected for processing. It is recognized that, in alternative embodiments, certain actions could be taken upon a determination that there are no defects in a print, such as marking the print "good."

If the visual image is determined to be characterized by an image-quality level outside a predetermined range (the answer is "YES"), then processing continues in the flow diagram shown on FIG. 3B by way of flow connector 300B. As shown in FIG. 3B at step 312, a notification of a defective print is sent to other print processing devices in the print inspection system 104. Some of these devices, such as the previously-described sort marker 152 or packaging station 156, could be disposed along the work path 116. Other devices, such as batch manager 160 or second storage medium 144, may not be disposed on the work path 116, but receive the information for subsequent processing. The notification may also be sent to still other print processing devices (not shown), such as a website server connected to an interconnected computer network like the Internet, so that a consumer or a retail clerk can log on from a remote location to check the image-quality status of a particular set of prints.

If the notification is sent to a sort marker 152, then the sort marker 152 applies an infrared light absorbent sticker or ink-jet printer mark to the defective print in a step 314. If the notification is sent to a batch manager 160, then, in a step 316, batch ~~manager 160 updates its electronic record for that particular print, and, at the appropriate~~ time, sends a reject instruction to packaging station 156. Finally, in a step 318, packaging station 156 sorts the defective print 180 into reject bin 188 and the good prints 184 into keep bin 190. The defective prints are then ready for discarding or further processing, as the case may be. Step 320 determines whether there are more prints to be inspected. If the answer is "YES," then processing returns to step 308 by way of flowchart connector 30A. Otherwise, processing is complete.

With reference now to FIG. 4, a more complete description of a computer system suitable for use with the preferred embodiment of the present invention is provided. The computer system 402 includes one or more processors, such as a processor 404. The processor 404 is connected to a communication bus 406. Various software embodiments are described in terms of this exemplary computer system. After reading this description,

it will become apparent to a person skilled in the relevant art how to implement the invention using other computer systems and/or computer architectures.

The computer system 402 also includes a main memory 408, preferably random access memory (RAM), and can also include a secondary memory 410. The secondary memory 410 can include, for example, a hard disk drive 412 and/or a removable storage drive 414, representing a floppy disk drive, a magnetic tape drive, an optical disk drive, etc. The removable storage drive 414 reads from and/or writes to a removable storage unit 418 in a well-known manner. The removable storage unit 418, represents a floppy disk, magnetic tape, optical disk, etc. which is read by and written to by the removable storage drive 414. As will be appreciated, the removable storage unit 418 includes a computer usable storage medium having stored therein computer software and/or data.

In alternative embodiments, the secondary memory 410 may include other similar means for allowing computer programs or other instructions to be loaded into the computer system 402. Such means can include, for example, a removable storage unit 422 and an interface 420. Examples of such can include a program cartridge and cartridge interface (such as that found in video game devices), a removable memory chip (such as an EPROM, or PROM) and associated socket, and other removable storage units 422 and interfaces 420 which allow software and data to be transferred from the removable storage unit 422 to the computer system 402.

The computer system 402 can also include a communications interface 424. The communications interface 424 allows software and data to be transferred between the computer system 402 and external devices. Examples of the communications interface 424 can include a modem, a network interface (such as an Ethernet card), a communications port, a PCMCIA slot and card, etc. Software and data transferred via the communications interface 424 are in the form of signals 426 that can be electronic, electromagnetic, optical or other signals capable of being received by the communications interface 424. Signals 426 are provided to communications interface via a channel 428. A channel 428 carries signals 426 and can be implemented using wire or cable, fiber optics, a phone line, a cellular phone link, an RF link and other communications channels.

In this document, the terms "computer program medium" and "computer usable medium" are used to generally refer to media such as the removable storage device 418, a

hard disk installed in hard disk drive 412, and signals 426. These computer program products are means for providing software to the computer system 402.

Computer programs (also called computer control logic) are stored in the main memory 408 and/or the secondary memory 410. Computer programs can also be received via the communications interface 424. Such computer programs, when executed, enable the computer system 402 to perform the features of the present invention as discussed herein. In particular, the computer programs, when executed, enable the processor 404 to perform the features of the present invention. Accordingly, such computer programs represent controllers of the computer system 402.

In an embodiment where the invention is implemented using software, the software may be stored in a computer program product and loaded into the computer system 402 using the removable storage drive 414, the hard drive 412 or the communications interface 424. The control logic (software), when executed by the processor 404, causes the processor 404 to perform the functions of the invention as described herein.

In another embodiment, the invention is implemented primarily in hardware using, for example, hardware components such as application specific integrated circuits (ASICs). Implementation of such a hardware state machine so as to perform the functions described herein will be apparent to persons skilled in the relevant art(s).

In yet another embodiment, the invention is implemented using a combination of both hardware and software.

The present invention has been disclosed and described herein in what is considered to be its most preferred embodiments. It should be noted that variations and equivalents may occur to those skilled in the art upon reading the present disclosure and that such variations and equivalents are intended to come within the scope of the invention and the appended claims.

CLAIMS

What I claim is:

1. A print inspection system, comprising:

a transport mechanism for moving a length of paper along a work path, said length of paper containing a plurality of prints;

a scanner positioned along said work path, said scanner being configured to capture a visual image of each of said plurality of prints;

means, coupled to said scanner, for converting said visual image into a digital file corresponding to said visual image; and

an electronic processor, wherein said electronic processor determines whether said visual image is characterized by an image-quality level that falls outside a predetermined image-quality range.

2. The print inspection system of claim 1, wherein said electronic processor is comprised of:

a neural network processor that is trained to recognize a digital file having an image-quality level that falls outside a predetermined range of image-quality levels.

3. The print inspection system of claim 1, further comprising means for storing said digital file on a first storage medium.

4. The print inspection system of claim 3, further comprising means for storing the result of said image-quality level determination on a second storage medium.

5. The print inspection system of claim 1, further comprising:

means, responsive to said electronic processor, for marking prints corresponding to visual images characterized by an image-quality level that falls outside said predetermined image-quality range.

6. The print inspection system of claim 5, further comprising:

means for discarding prints corresponding to visual images having image-quality levels that fall outside said predetermined image-quality range.

7. The print inspection system of claim 1, further comprising:

means for tracking the current location of a print as it moves along said work path; and

means for transmitting the image-quality level of said print and current location of that print on said work path to a print-processing device.

8. The print inspection system of claim 1, further comprising means for identifying a leading and a trailing edge of each print as it moves along said work path..

9. The print inspection system of claim 8, wherein said means for identifying comprises:

a cut-marker positioned near the start of said work path, wherein said cut-marker inserts cut-marks on said length of paper corresponding to the trailing edge of each print; and

a cut-mark sensor.

10. The print inspection system of claim 7, wherein said means for tracking comprises:

a cut-marker positioned near the start of said work path, wherein said cut-marker inserts cut-marks on said length of paper corresponding to the trailing edge of each print; and

a cut-mark sensor.

11. A method for inspecting prints, comprising the steps of:

feeding into a work path a length of paper containing a plurality of prints;

capturing a visual image of each print;

converting said visual image of each print into a digital file corresponding to said visual image;

determining whether said visual image is characterized by an image-quality level that falls outside a predetermined image-quality range; and

repeating said determining step for each digital file created in said converting step.

12. The method of claim 11, wherein said determining step is carried out using an electronic processor.

13. The method of claim 11, wherein said determining step comprises:

training a neural network processor to recognize visual images characterized by an image-quality level that falls outside said predetermined image-quality range.

14. The method of claim 13, wherein said training step comprises:

training said neural network to recognize a visual image that contains no useful content.

15. The method of claim 13, wherein said training step comprises:

training said neural network to recognize a visual image that has a physical defect.

16. The method of claim 13, wherein said training step comprises:

training said neural network to recognize a visual image that has a repetitive exposure error.

17. The method of claim 13, wherein said training step is accomplished by presenting said neural network processor with a histogram of the sampled visual image.

18. The method of claim 13, wherein said training is accomplished by presenting said neural network processor with statistical abstractions of sample visual images.

19. The method of claim 13, wherein said training comprises presenting said neural network processor with raw pixel data corresponding to sample visual images.

20. The method of claim 13, wherein said training is accomplished by presenting said neural network processor with a subset of raw pixel data corresponding to sample visual images.

21. The method of claim 11, further comprising the step of storing said digital file on a first storage medium.

22. The method of claim 11, further comprising the steps of:

marking prints corresponding to visual images characterized by an image-quality level that falls outside said predetermined image-quality range to form marked prints; and

discarding said marked prints containing said markings.

23. The method of claim 11, further comprising the step of tracking the current location of each print as it moves along said work path.

24. The method of claim 23, further comprising the step of:

transmitting image-quality level of a print and current location of that print on said work path to a print-processing device.

25. The method of claim 24, wherein said image-quality level and current location are transmitted to said print-processing device via a link to an interconnected computer network.

26. A method for inspecting prints, comprising the steps of:

feeding into a work path a length of paper containing a plurality of prints;

marking a leading or trailing edge of each print with cut-marks;

sensing the location of said cut-marks as said length of paper moves along said work path; and

in response to said sensing,

capturing a visual image of each print,

converting said visual image into a digital file corresponding to said visual image, and

determining whether said visual image is characterized by an image-quality level that falls outside a predetermined image-quality range.

27. The method of claim 26, wherein said determining step is carried out using an electronic processor.

28. The method of claim 26, wherein said determining step comprises:

training a neural network processor to recognize visual images characterized by an image-quality level that falls outside said predetermined image-quality range.

29. A method for inspecting prints, comprising the steps of:

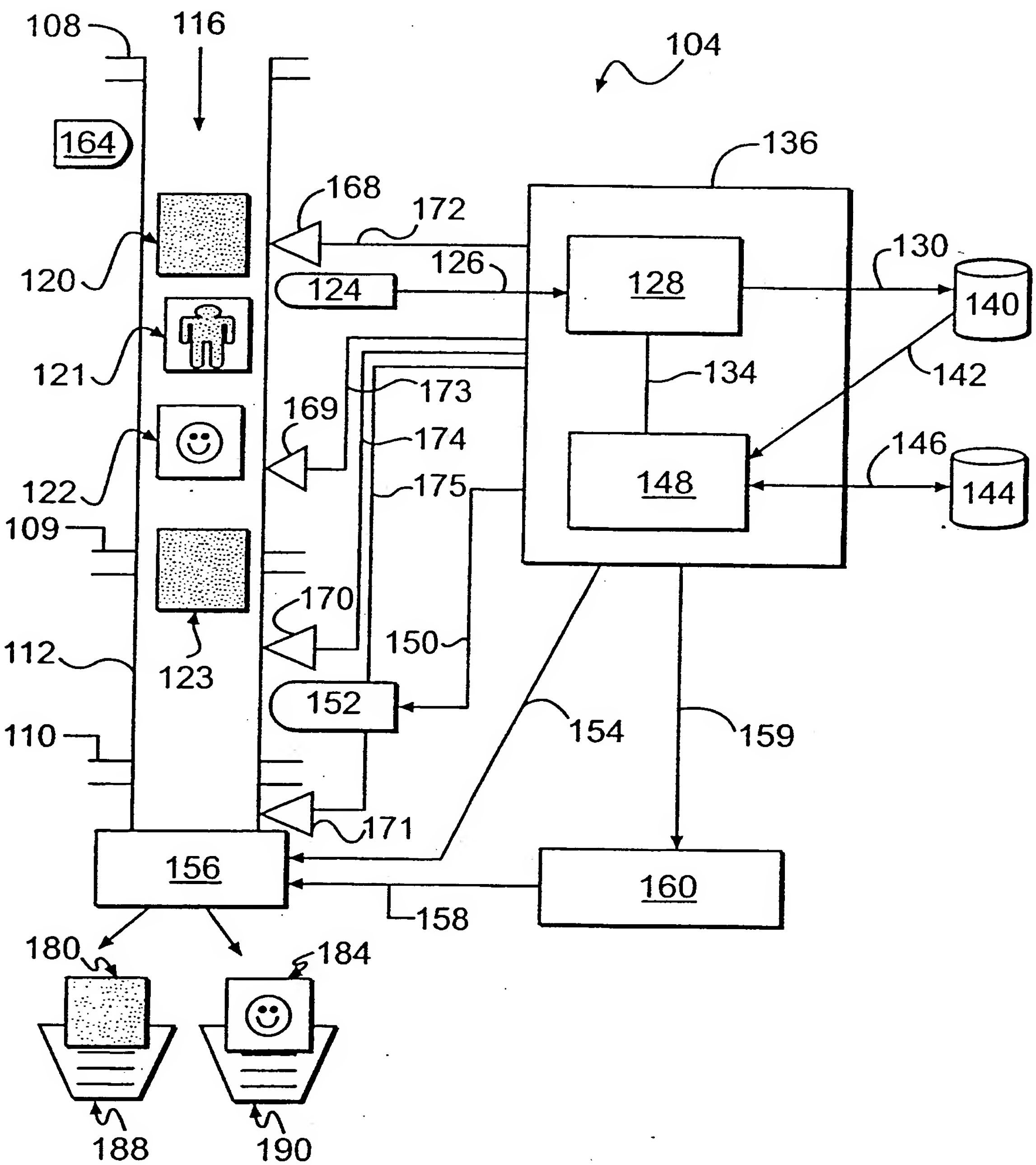
feeding into a work path a length of paper containing a plurality of prints;

capturing a visual image of each print;

converting said visual image of each print into a digital file corresponding to said visual image;

determining via an electronic processor whether said visual image is characterized by an image-quality level that falls outside a predetermined image-quality range; and

repeating said determining step for each digital file created in said converting step.


108
116
104
164
136
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172
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124
128
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121
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169
174
146
175
122
148
144
109
170
150
112
123
152
154
159
110
171
156
160
158
180
184
188
190

FIG. 1

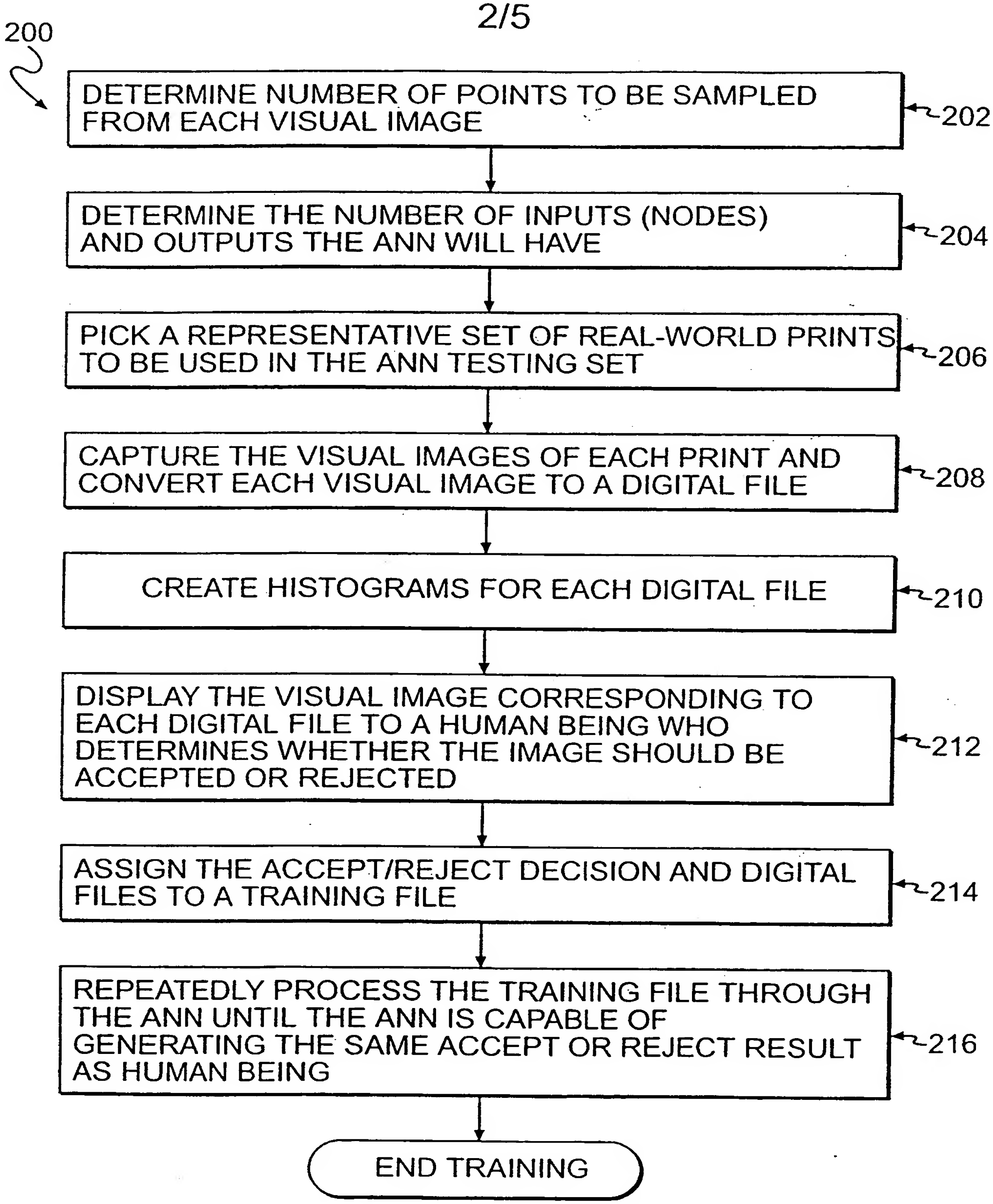
200
DETERMINE NUMBER OF POINTS TO BE SAMPLED FROM EACH VISUAL IMAGE
202
DETERMINE THE NUMBER OF INPUTS (NODES) AND OUTPUTS THE ANN WILL HAVE
204
PICK A REPRESENTATIVE SET OF REAL-WORLD PRINTS TO BE USED IN THE ANN TESTING SET
206
CAPTURE THE VISUAL IMAGES OF EACH PRINT AND CONVERT EACH VISUAL IMAGE TO A DIGITAL FILE
208
CREATE HISTOGRAMS FOR EACH DIGITAL FILE
210
DISPLAY THE VISUAL IMAGE CORRESPONDING TO EACH DIGITAL FILE TO A HUMAN BEING WHO DETERMINES WHETHER THE IMAGE SHOULD BE ACCEPTED OR REJECTED
212
ASSIGN THE ACCEPT/REJECT DECISION AND DIGITAL FILES TO A TRAINING FILE
214
REPEATEDLY PROCESS THE TRAINING FILE THROUGH THE ANN UNTIL THE ANN IS CAPABLE OF GENERATING THE SAME ACCEPT OR REJECT RESULT AS HUMAN BEING
216
END TRAINING

FIG. 2

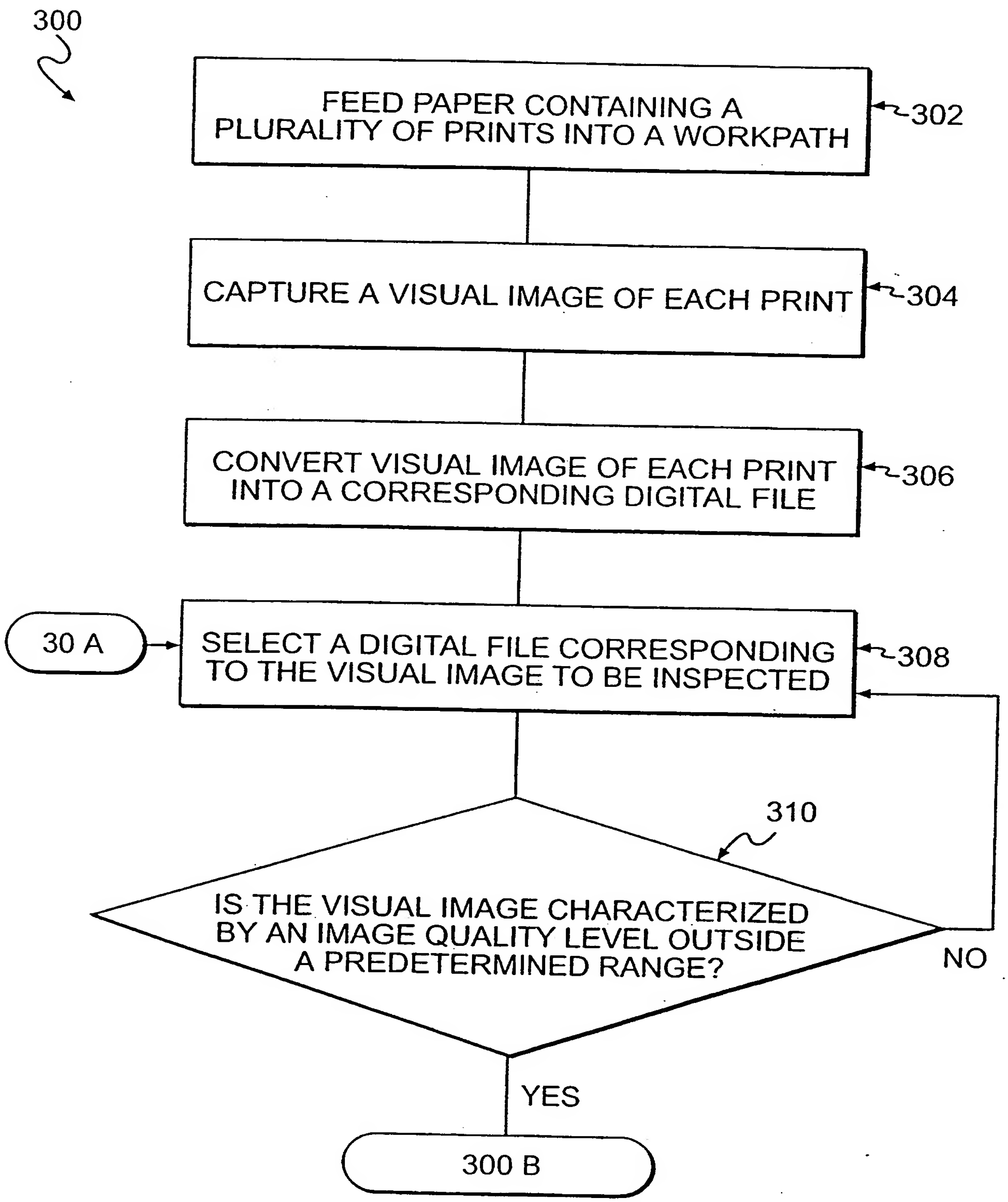
300
FEED PAPER CONTAINING A PLURALITY OF PRINTS INTO A WORKPATH
302
CAPTURE A VISUAL IMAGE OF EACH PRINT
304
CONVERT VISUAL IMAGE OF EACH PRINT INTO A CORRESPONDING DIGITAL FILE
306
30 A
SELECT A DIGITAL FILE CORRESPONDING TO THE VISUAL IMAGE TO BE INSPECTED
308
310
IS THE VISUAL IMAGE CHARACTERIZED BY AN IMAGE QUALITY LEVEL OUTSIDE A PREDETERMINED RANGE?
NO
YES
300 B

FIG. 3A

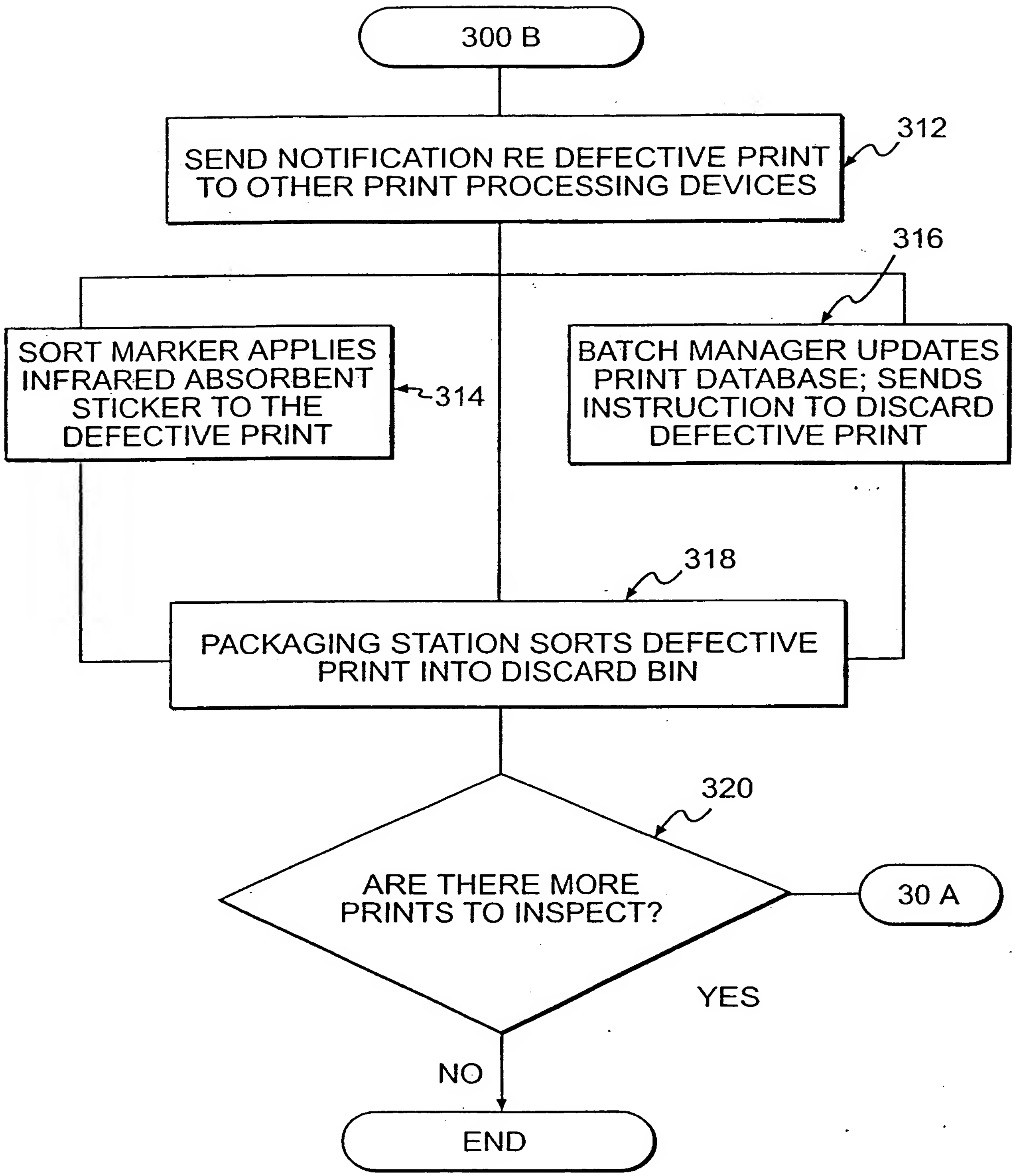
300 B
SEND NOTIFICATION RE DEFECTIVE PRINT TO OTHER PRINT PROCESSING DEVICES
312
316
SORT MARKER APPLIES INFRARED ABSORBENT STICKER TO THE DEFECTIVE PRINT
314
BATCH MANAGER UPDATES PRINT DATABASE; SENDS INSTRUCTION TO DISCARD DEFECTIVE PRINT
318
PACKAGING STATION SORTS DEFECTIVE PRINT INTO DISCARD BIN
320
ARE THERE MORE PRINTS TO INSPECT?
30 A
YES
NO
END

FIG. 3B

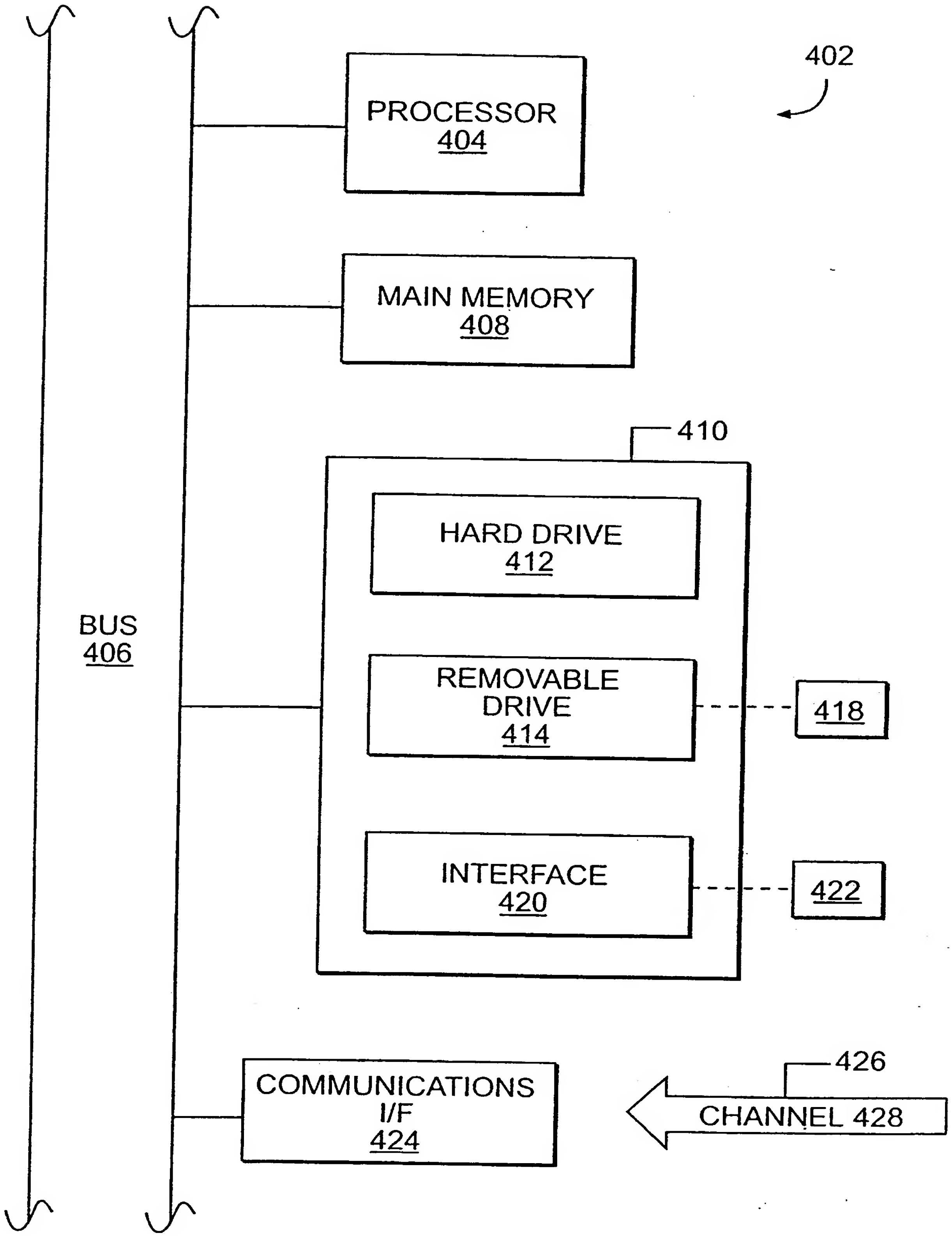
402
PROCESSOR
404
MAIN MEMORY
408
410
HARD DRIVE
412
BUS
406
REMOVABLE
DRIVE
414
418
INTERFACE
420
422
COMMUNICATIONS
I/F
424
426
CHANNEL 428

FIG. 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/22352

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) :G06K 9/36; G06E 3/00
US CL :702/179, 180; 382/233, 251, 252, 237, 239; 358/361.2, 429, 430
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 702/179, 180; 382/233, 251, 252, 237, 239; 358/361.2, 429, 430

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WEST 2.0

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5,841,904 A (Sugiura) 24 November 1998 (24.12.1998) see whole document	1-29
Y	US 5,309,526 A (Pappas et al)) 03 May 1994 (03.05.1994) see whole document	1-29
A	US 5,550,951 A (Woodall) 27 August 1996 (08.27.1996) See whole document	1-29

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search 23 SEPTEMBER 2000	Date of mailing of the international search report 06 DEC 2000
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer KAMINI SHAH Telephone No. (703) 308-0956